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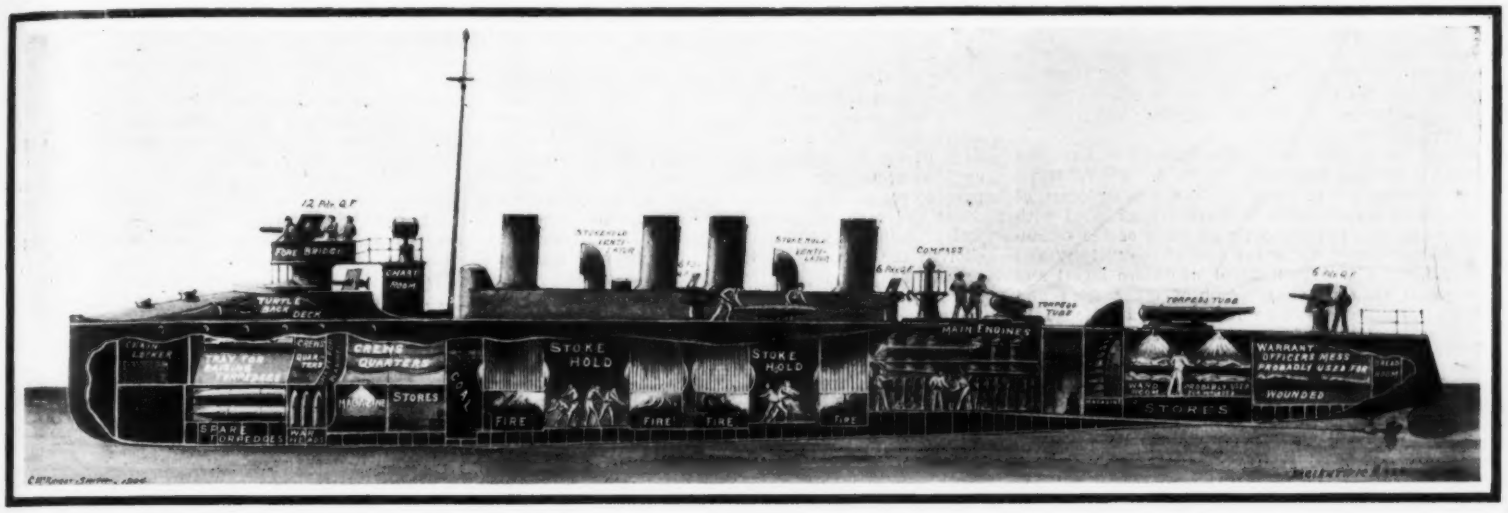


SECTIONAL DIAGRAM, SHOWING THE INTERIOR OF A JAPANESE TORPEDO-BOAT DESTROYER.

FLEET OF BATTLESHIPS SURPRISED BY NIGHT ATTACK OF TORPEDO-BOAT DESTROYERS.

THE TORPEDO BOAT IN MODERN WARFARE.

THE DEVELOPMENT OF THE TORPEDO-BOAT DESTROYER.*

By W. J. HARDING.

FROM very early times the glamor of the torpedo—or the "infernal machine," as it has been called—has occupied people's attention and prompted its usage; for the idea is that you may, by a sort of "hitting below the belt," destroy your enemy with but little risk to yourself; and, further, when there is risk involved, it would be borne by only a very small number of assailants, and that in fact, as represented by novelists and others, risks to each individual may be less than that of the players in a football scrimmage.

Torpedoes may be classed as fixed and moving. Of the fixed ones our experience as a nation was gained during the Russian war of the fifties, when at least one English ship was slightly injured in the Baltic by the explosion of a torpedo under her, and some officers and men were injured by the explosion of captured torpedoes while they were being taken apart. During that war also was used what may be described as a moving torpedo, an English sailor being credited with swimming into the harbor of Sebastopol and fixing an infernal machine under the counter of a line-of-battle ship, for which bravery he was rewarded; but I believe the ship was not blown up.

In 1858 the British navy had experience of a moving torpedo, a Chinese invention. H. M. S. "Niger," while lying in Fatee Creek ready for the bombardment of Canton, was torpedoed by a moving junk filled with gunpowder, etc., towed from each bank of the stream and cleverly placed under the bow of the "Niger" and exploded. The damage inflicted was more moral and intellectual than physical. And of other fixed and moving torpedoes we have lately had knowledge in the operations in the far eastern seas.

I may also remind you that the moving torpedo, carried on the end of a spar, was used during the civil war in North America, notably when Commander Cushing blew up the Confederate warship "Albemarle." Another attack by the Confederates, in 1864, with the spar torpedo, was successful in sinking the Federal man-of-war "Housatonic," the attacking boat being sucked into the breach made by the explosion and also foundering with all hands. Also during that war there were several cases of ships being destroyed by anchored mines.

After that we had the Harvey towing torpedo, which was an adaptation of the canal barge towed from the bank, or of what is known as the salmon poacher's "otter" with baited hooks, the poacher walking along the river's bank and towing his otter, which keeps mid-stream, and so catching his salmon. These otters can also be made to alter the direction of their motion by a strong pull on the towing line, which enables the poacher to retrace his steps, still towing his otter mid-stream. After that we had the Whitehead invention, which has necessitated alterations and additions both to tactics and to shipbuilding.

Not always has perfection been obtained without early fatalities. A very promising officer, Lieut. Meade, brother of the present Earl Clanwilliam, was blown up when manipulating a torpedo of his own invention in the sixties. And later on in the seventies, an engineer officer was killed and another maimed in working the Whitehead apparatus, due to escape of compressed air. There have been other incidents giving maiming of limbs, which is a toll learners have had to pay in manipulating these and other deadly weapons; and happily the history shows that whether boiler explosions, machinery disasters, or other incidents giving mortality, there are always many living volunteers to take a dead man's place.

The Whitehead torpedo is fairly well known. This is the invention of a marine engineer, and is a weapon which marine engineers are most aptly fitted to manipulate. Its original propelling apparatus was by compressed air working compound oscillating engines and driving a single propeller, giving rather a low speed.

The first vessel in the British navy for using this torpedo was the "Vesuvius." This was a vessel low in the water, having a peace funnel of the ordinary type pointing to the sky and a war funnel horizontally along her deck to discharge smoke right aft. She was fitted with induced draft. She had a submerged torpedo tube pointing right ahead, from which the torpedo was ejected by a telescopic apparatus actuated by compressed air. It was early seen in this vessel that the speed of the torpedo should be increased, for it is one of the legends of the navy that when she did fire an actual live torpedo from her tube at a hulk, she being under way, those looking over the bows of the vessel saw that the "Vesuvius" would soon overtake the torpedo, and perhaps be blown up herself. Higher speeds of torpedo were afterward obtained by adopting the Brotherhood three-cylinder engine, and this has been continued.

The development of the torpedo boat and destroyer is due primarily to the fact that it was found that these Whitehead torpedoes could be discharged from above water. The first experiment was made from the deck of an old sailing vessel, the torpedo launched, and the regulating valve for the engine tripped as it passed over the side, when it was seen that the torpedo dived and soon regulated itself to the depth required and propelled itself in a straight line. From this was evolved the ordinary deck torpedo tube now used in torpedo boats and destroyers.

The torpedo "drop gear" fitted to vedette boats, etc., was an adaptation invented by Engineer Rear-Admiral J. T. Corner, and is an arrangement of tongs which is lowered from the boat's side, submerges the torpedo, and on tripping its regulating valve, thus setting the propeller in motion, releasing the tongs at the same time, the torpedo starts and soon finds its depth. These vedette boats of wood of 1878 were 48 feet long and 12 knots speed, and have been developed to 56 feet long. Special boats of this class, by J. Samuel White, of Cowes, have obtained 19 knots on trial.

About 1873 some very fast vessels began to be constructed on the Thames. These vessels were marvelous in their low weight and high power. They completely upset the theories which are written in some books on naval architecture, in which it was laid down that speed at sea could be obtained only by enormous increase of dimensions of the vessel, and it was inferred that the speed of small vessels could be put to only a certain limit, dependent on length.

In 1875, Messrs. Yarrow constructed a torpedo launch of the then high speed of 13 knots, fitted with a spar torpedo, and made a war test by blowing up a barge on the Thames prior to shipment and delivery to a South American power. Sir John Thornycroft was the builder of the "Miranda," in 1872. This vessel was 45 feet 6 inches long, and obtained a speed of 16.2 knots per hour. This firm constructed the first large torpedo boat for H. M. navy. She was the "Lightning," completed in 1877, her length 87 feet, speed 18½ knots, and she did many years of constant service at Portsmouth. Also in 1877 the Russian government obtained from home and two foreign firms 100 torpedo boats. A large number of these were built by, or to the design of, Messrs. Yarrow, celerity being required. They were 75 feet long by 10 feet beam, were required as small as possible for keeping the seas for a few days, and also adapted for transmission by rail. The first boat tried on the Neva obtained 18 knots speed.

Following the "Lightning," various batches of boats for our navy were constructed at various times up to 1889. These were by Messrs. Thornycroft, White of Cowes, and Yarrow. Their lengths were from 113 feet to 130 feet, giving horse-powers from 730 to 1,100, and speeds from 20 to 23 knots. Some of the earlier and shorter of these were dispatched to various stations—China, Cape of Good Hope, Australia, North America, India, etc. Most of these voyages were under their own steam. The longest voyages, from England to Vancouver Island *via* Sandy Point, were performed by two Yarrow boats. There were no incidents during these voyages engendering mistrust as to strength of hull. As to the crews, their normal state may be described as "dirty, but happy." In connection with this matter of strength of hull, of the destroyer class especially, it is much to be regretted that alarm was some few years ago created by irresponsible and untechnical writers—some of them neither naval nor expert, though called naval experts—who argued from wrong premises and preached ideas which, if followed, would cause a most useless and wasteful expenditure of public money.

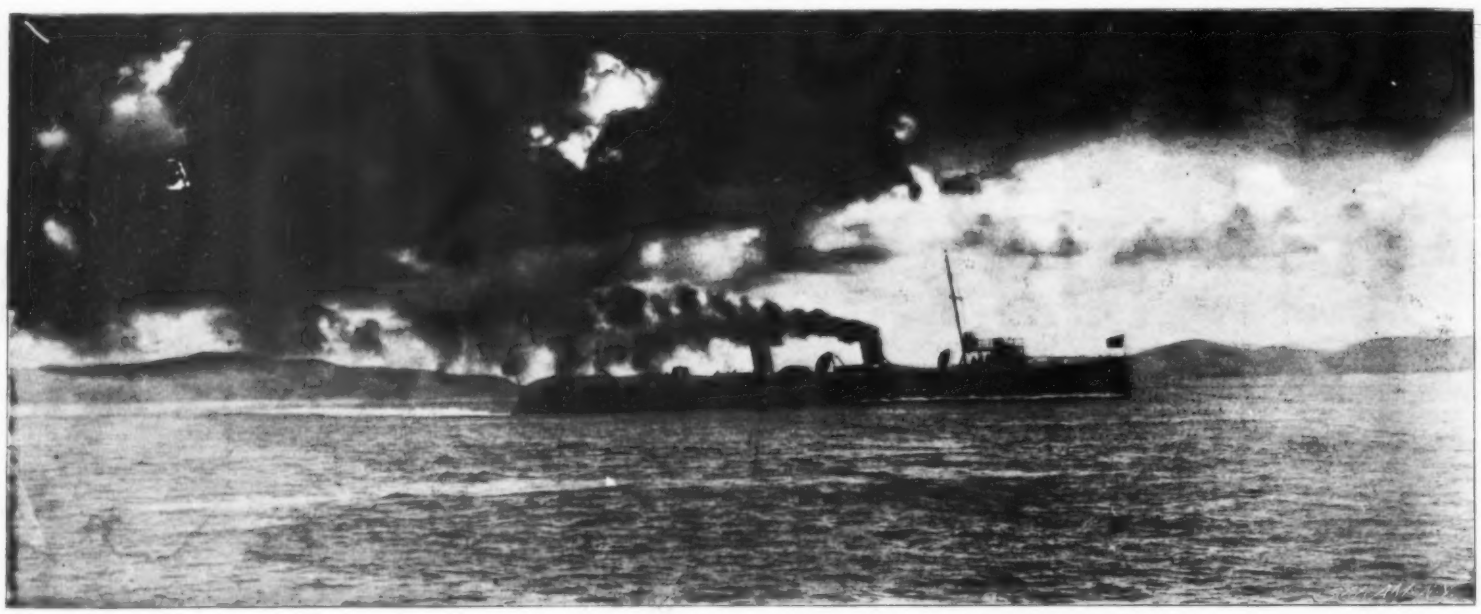
In the Chilian-Peruvian war, 1879-1881, spar torpedo boats were employed by both combatants. The blockade of Callao was commenced at about 5 A. M. on April 10, 1880, by the Chilian Thornycroft torpedo boat "Guacolda," an 11-knot craft, attacking the Peruvian man-of-war "Union," which was surrounded by timber booms. The boom was shattered, but the small-arm fire drove off the torpedo boat.

The gallant but unready Peruvians had only makeshift craft, which did good work, in that they caused the Chilian blockading fleet to proceed to sea daily at sundown and spend the night in a safe offing, the entrance to Callao Bay being patrolled by Chilian torpedo boats. In the middle watch of May 25 of that year, a Peruvian spar torpedo launch, some distance from the shore, was surprised by the "Guacolda," which chased her. The 18-knot Yarrow boat, the Chilian "Janeques," also chased and overtook the Peruvian, the result being that the Chilian was torpedoed and sunk, and the Peruvian foundered when returning. Gallant Lieut. Galves, badly wounded, and seven of his crew of sixteen were rescued by the "Guacolda"; his surgeon, Uriarte, and eight men were killed. The surgeon was given an impressive public funeral in Lima. The Chilian loss was two men, the remainder escaping in boats seized from a vessel lying in the out-of-fire zone.

It will be remembered that this war was remarkable for the destruction of two vessels by torpedoes. In one case the transport "Loa" captured a coasting barge adrift full of vegetables, fruit, poultry, and other good things, which were heartily welcomed by the crew, who had had a long diet of sun-dried beef and biscuit. On examination of the barge it did not show any explosives; but as the welcomed cargo was unloaded from the barge alongside the "Loa," mechanical arrangements were such that when the weight in the barge had been very much reduced an explosion ensued, which blew in the side of the "Loa" and sank her with loss of life of 145 men of a crew of 200.

Another case was the "Covadonga." She had been captured from the Spaniards by the Chilians many years before by a deception, and another deception was her doom. This vessel captured a little skiff which was adrift, and, in hoisting her on board the "Covadonga" was dynamited and sunk. There were moving torpedoes supplied for that war, but they did no destruction. They were of the "awash" principle, controlled from a station by wire. They were not regarded as satisfactory by the Peruvians. In one case it is said that one got out of control and returned toward the Peruvian ship "Huascar," from which it was being operated, and only the gallantry of Lieut. Diez Canseco of that ship saved her, he jumping overboard and diverting the torpedo. The Peruvian Admiral Grau was so disgusted by these weapons that he

* Read before the Institute of Marine Engineers, England



THE TWIN SCREW TORPEDO BOAT DESTROYER "FARRAGUT" ON HER TRIAL TRIP.

THE TORPEDO BOAT IN MODERN WARFARE.

landed them and buried them in the public cemetery at Iquique.

Later, in 1891, in those South Pacific waters, the Whitehead was used. In one case a Whitehead was fired from a picket boat at a large Chilian mail ship, but did no damage, being found next morning minus its head, no explosion happening. But the ironclad "Blanco Encalada" fared worse. Some six Whiteheads were fired at her, of which one only seems to have struck, and its charge of 58 pounds of guncotton knocked a hole in her side 15 feet fore-and-aft by about 7 feet width. She sank in less than five minutes, losing 150 officers and men. Of the eleven officers missing six were engineers. The only engineer who was saved was washed up one of the ventilators. Later on in that war a spar torpedo picket boat was destroyed by the explosion of her own torpedo, and five men were blown up or drowned.

In 1853 torpedo warfare was conducted on the Brazilian coast. The ironclad "Aquidaban" was struck forward by a fish torpedo having 125 pounds of guncotton, which caused the two forward compartments to fill but did not sink her. In this case one hit in four discharges was given.

The precursor of the destroyer class was evolved about 1884. Hitherto the plan had been to give torpedo boats an alternative armament, so that half of the boats might be employed for firing torpedoes, the others acting as torpedo-boat destroyers, the boats armed by the small guns resisting attacks of torpedo boats. But as the speeds would be about the same in each, it is evident that neither could decrease the range of the other when attacking or escaping. Perhaps the first approach to the destroyer was the production of John Samuel White, of Cowes. This was a vessel added to the British navy in 1885. She was 150 feet long, and so larger than boats hitherto in use, which were single-screw boats. She was fitted with twin screws and with more power—a larger vessel and better sea boat, and of higher sea speed than they. In the British navy she did good work as the commodore of the flotilla.

Another vessel, 200 feet long, 2,900 horse-power, named the "Sea Serpent," was also laid down by that firm in 1885, and obtained a speed of 23.8 knots with a load of 20 tons, and 21.5 knots with a load of 90 tons. The curt term "destroyer" not then being in use, she was termed an "exaggerated torpedo boat." At that time "Rattlesnakes" were in fashion, but the "exaggerations" are now a survival of the fittest. Her speed was a little disappointing, the shallow water of Stokes Bay not favoring speed. Also, if subsequent knowledge as to material of propellers had been available, she might have obtained 25 knots, and so fulfilled most of the conditions which were afterward required in torpedo-boat destroyers. She was eventually acquired by the Chinese.

Messrs. Yarrow & Company constructed the "Kotaka" in 1885 for the Japanese government. She was 170 feet long and fitted with twin screws, and practically an armored destroyer, being fitted with armor 1 inch thick around the machinery and boiler compartments, sufficient to resist the fire from the torpedo boats as then armed. This vessel led the attack, with other torpedo boats, on the Chinese ships at Port Arthur. It is not generally known that in that Japanese attack the weather was so bitterly cold that it actually froze the sea-sprayed torpedoes in their carriages, and that of eight torpedoes which were attempted to be fired against the Chinese men-of-war only two were actually fired, the others being frozen in their tubes, and could not be ejected till thawed out. Perhaps in reference to this incident I may suggest that the recent operations in China seas have also been very much influenced by the freezing weather, for engineers well know that compressed air in escaping is frozen, and that where compressed air is used for operating machinery the exhaust pipe must be very short, and to carry a Whitehead charged with compressed air which will rapidly assume the temperature of the surrounding atmosphere, which may be initially several degrees below freezing point, this expanded air exhausting from the Brotherhood engine through a long hollow propeller shaft, may cause such freezing in that shaft as will decrease the speed and range of the torpedo, and perhaps render it inoperative.

About 1893 the British navy gave orders for torpedo boats which were to be of higher speed than hitherto; and not only of higher speed, but to obtain this speed carrying a greater load than before. These boats were Nos. "88" to "97" of the British navy, constructed by Yarrow, Thornycroft, and White, and one of them by Laird, of Birkenhead. Some were fitted with locomotive boilers; those by Thornycroft with water-tube boilers; one by Yarrow also with water-tube boilers. Trials of these vessels showed that certainly for this service the water-tube boiler was far preferable to the locomotive boiler.

(To be continued.)

WATER POWER AT HIGH PRESSURE.

ONE cubic foot of water per second, falling 1,000 feet, develops more than 11 horse-power.

This striking fact may well call attention to the great, undeveloped water powers in all of the mountainous sections of the United States. Hundreds of such powers now go to waste almost unnoticed, because of the common idea that a large volume of water is necessary where much energy is to be developed. As a matter of fact, many an unpretentious mountain brook expends enough power in grinding its rocky bed to turn the wheels of a great city.

Proof of this is easily reached by considering the figures for rainfall, runoff, and elevation that apply to large parts of the country. Take, for illustration, an annual fall of rain and snow that amounts to 36 inches of water on a level, and is generally reached in the higher parts of the New England, Middle, and Southern States. With this rainfall each square mile of territory receives 83,635,200 cubic feet of water annually. This water must either soak into the ground and reappear elsewhere in springs, or evaporate, or else run off over the surface of the ground, and a part moves in each of these ways. That portion which runs off over the surface is available for power production. If a quantity of water represented by a depth of one foot on a level runs off over the surface of the ground, each square mile furnishes 27,874,400 cubic feet annually. This volume of water develops some 86,700 horse-power hours, if allowed to fall 1,000 feet. On the assumption that the flow of water will be regulated, and used during only 3,000 hours per year, the runoff of a depth of one foot from one square mile will generate 28.9 gross horse-power during 300 days of ten hours each, under the conditions named. With any variation of the water head from 1,000 feet, the power will, of course, vary in like proportion. That is, a fall of 500 feet would develop 14.4 horse-power during 3,000 hours with the volume of water named, and a fall of 2,000 feet would yield 57.8 horse-power. So too the number of horse-power hours will vary directly with the total quantity of water available. The ratio of the volume of water passing down the bed of a stream to the volume that annually falls on its drainage area, known as the percentage of runoff, is very irregular in different cases, and ranges from less than one-tenth to fully seven-tenths. For many of the streams in the mountainous parts of the States along the Atlantic coast a runoff of 50 per cent is not too high. With an annual precipitation of 36 inches of water on a level, a runoff of 50 per cent gives a stream of 41,817,600 cubic feet of water per year from each square mile of its drainage area, or a discharge of 3.87 cubic feet per second during 3,000 hours. This rainfall and runoff combined with a fall of 1,000 feet thus yield about 129,900 horse-power hours for each square mile of drainage area. If this amount of energy is used at a uniform rate during 3,000 hours, it develops 43.3 horse-power. From these figures it may be seen that a small drainage area will often supply enough water to develop a very large power, if a head of 1,000 or more feet can be obtained. A small mountain stream will often have between one and two miles of drainage area per mile of length, even where located in a very narrow valley, so that the runoff from twenty to fifty square miles is available within a few miles of its source. With a drainage area of fifty square miles, the runoff on the basis of the above moderate assumptions would develop 2,165 gross horse-power during 3,000 hours per year, or 6,495,000 horse-power hours.

In order to make this energy available for useful work there must in every case be a large storage capacity, because the fall of water is very irregular from day to day and month to month. Small streams in mountainous country often show maximum discharge rates that are twenty to fifty times as great as the minimum, and this great variation in the discharge gives such streams small value for power production, before a relatively large storage capacity is provided. Take, for illustration, the case assumed above, with a drainage area of fifty square miles and an annual runoff represented by a depth of 18 inches of water on a level over this drainage area. With most of the annual rainfall concentrated in the smaller part of the year, it might be desirable to provide a storage capacity for one foot depth of water on a level over the entire drainage area. This would mean the storage of fifty times 27,878,400 cubic feet of water, or 1,393,920,000 cubic feet. With an average depth of 20 feet in this reservoir, its area would be 2.5 square miles, or one-twentieth of the drainage area. Such a reservoir might involve only a moderate investment in a hilly country with deep valleys.

California and the entire Rocky Mountain region afford the best opportunities for the development of water power under high heads, because of the great changes in elevation there, and numerous examples of such powers are to be found in these sections. One such is the hydro-electric plant on Bear Creek that delivers energy to the 33,000-volt transmission that runs to Los Angeles. At this plant the head of water is more than 1,900 feet, so that one cubic foot of water per second develops twenty gross horse-power. In Colorado, near Pike's Peak, an electric plant is operated with water under a head of 2,500 feet, which is believed to be the greatest in this country or the world, that has been developed. While such heads of water cannot, perhaps, be duplicated at developments in the East, numerous cities exist along the Appalachian chain of mountains, from Maine to Georgia, where water heads of 500 to 1,000 feet can be obtained for power plants. At a recent development in New England, a head of about 470 feet was procured for a pipe line some three miles long. The drainage area of the stream above the dam where the head of this pipe is located is only 15 square miles, and of this area the reservoir behind the dam covers 800 acres.

As there are 640 acres to the square mile, this reservoir covers 8.3 per cent of its drainage area. The storage capacity of this reservoir is 435,000,000 cubic feet, which represents a layer of water 1.01 feet thick on a level over its entire drainage area. In a case where the total drainage area is 24 square miles, the storage reservoirs cover 1,120 acres and have a combined capacity of 498,000,000 cubic feet of water. The generating station where the runoff from this 24 square miles is utilized under a head of 222 feet has a capacity of 1,600 kilowatts. Plans for a plant in the Berkshire Hills of Massachusetts, not yet built, show a water head of more than 800 feet.

PAVEMENTS FOR RESIDENCE STREETS.

RESIDENCE streets may be paved with stones or brick; with wood or asphalt; or with sand or gravel rolled down and pressed together into the hard, smooth, yet granular and porous, surface which we all know in the commonest of streets, the so-called "macadam." Even in great cities the "macadamized" street is often the commonest—as for example in Boston, where out of 490 miles of streets 280 miles were, in 1900, of this kind.

Granite blocks, useful enough for streets in which there is much teaming, are highly objectionable for residence streets of every kind. In spite of the fact that in our eastern cities and large towns they often come from Mt. Desert or Deer Isle or other quiet islands on the coast of Maine, they are extremely noisy. In this respect they resemble, perhaps, human beings, transplanted from the country to the city and there displaying characteristics previously latent and unsuspected. Moreover, granite blocks are not merely noisy but, unless their joints are very carefully filled with pitch, they are not impervious to liquids, and are hence objectionable for the reason that filth, liquid as well as solid, may find its way between and below the individual stones and there ferment, giving rise to noxious gases.

Bricks make a noisy paving, and, unless perhaps for tenement districts, are therefore out of place on residence streets. Besides, they often become wavy when much worn, and thus give standing places for puddles or pockets for dust and filth. Asphalt, in spite of some defects, has much to recommend it. It gives a watertight surface, is smooth, readily swept and washed, and is not nearly as noisy for teams as are granite blocks or bricks. Moreover, it dries quickly after a rain, and if kept clean is neither muddy nor dusty. It is, however, black and hot in summer, and always much more noisy than macadam. It is also at times very slippery for horses. But yet for many residence streets it may be strongly recommended.

There remains still another pavement for residence streets, not very widely used in the United States as yet, but much used in London and some other foreign cities, namely, wood. It seems at first sight curious that a young country like ours, and one having extensive forests, should in this respect fall behind an older country like England, in which wood is so scarce and dear that a wooden fence is sometimes considered a rare luxury. But when we learn that many kinds of wood are not suitable for making pavements, and that a wooden pavement does not so well stand a climate like ours, swiftly changing from very hot to very cold and from very wet to very dry, as one more even—then it becomes easier to see why England, with its ships returning from all parts of the globe bringing in merchandise at low cost and free of duty, and with a climate comparatively equable as to temperature and moisture and comparatively limited as to rainfall, may find it practicable to import and use wood for pavements, when we cannot.—Prof. William T. Sedgwick in Good Housekeeping.

BLEACHING OF FLOUR.

IN a paper read before the Académie des Sciences, E. Fleurent describes the researches which he carried out during the last year upon the bleaching of wheat flour. In the first place experiment shows that the only processes which have an industrial value are those which are based upon the use of peroxide of nitrogen prepared either by chemical action or by the action of a flaming arc upon atmospheric air. Pure oxygen when ozonized has no action upon the color of flour, and if ozonized air is found to bleach it, it is only where the latter is charged with nitrous product which comes off in the process. Besides, flour which is treated by ozone takes a disagreeable odor which makes it unfit for use.

When calculated as to bioxide of nitrogen, the quantity of nitrous product which is used in the bleaching varies with the kind of flour from 8 to 20 cubic centimeters per pound of flour. The flour which is thus bleached is not appreciably modified as to chemical composition, and accordingly in its practical value for bread-making. These flours give a bread in which the yellow color is more or less lightened. As the author showed previously, the action of nitrogen peroxide occurs upon the fatty matter, the yellowish oil which gives the flour a more or less creamy hue, but this action is not, as has been supposed, a destruction of the color by oxidation. Experiment shows that the bleaching coincides with a diminution in the iodine, and this may be considerable. It follows that the nitrogen peroxide is fixed upon the fatty matter as an addition to the latter, and the tint passes to an orange yellow. This has the effect of lessening the light-absorbing power of the oil or to make the fatty film which surrounds each grain of starch more transparent, so that the flour thus treated appears whiter. The bleaching by chemical treatment is different from the whitening by age, as the latter is due to the formation, by oxidation, of fixed and white fatty acids which by precipitating in the midst of the fatty matter lessen the apparent coloration. The fixation of the nitrogen peroxide upon the fatty matter of the flour allows of using a characteristic reaction based on the difference in the coloration of the soaps obtained from it. By benzine we extract the fatty matter of 50 grammes of the flour. After evaporating, we dissolve the oil in 3

cubic centimeters of amyl alcohol; place in a test-tube and add 1 cubic centimeter of alcohol made alkaline by potash. For normal flour we have no change of the yellow color, but for bleached flour the color changes to orange red more or less strong. We can thus detect as low as 5 per cent of bleached flour added to the normal flour.

[Concluded from SUPPLEMENT No. 1576, page 25250.]

CEMENT MORTAR AND CONCRETE: THEIR PREPARATION AND USE FOR FARM PURPOSES.*

By PHILIP L. WORMLEY, JR.

Molding and Curing Posts.

IT is recommended that only so much concrete be mixed at one time as can be used before it begins to harden; but if an unavoidable delay prevents the posts being molded until after the concrete has begun to set,

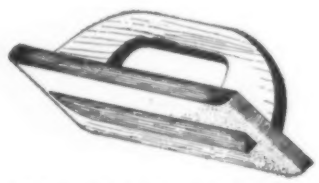


FIG. 10.—TOOL USED FOR BEVELING EDGES OF POSTS.

it is thought that a thorough regaging with sufficient water to restore normal consistency will prevent any appreciable loss of strength, though the concrete may have been standing one or two hours. In using a mold similar to those illustrated in Figs. 7 and 8, it is necessary to provide a perfectly smooth and even platform of a size depending upon the number of posts to be molded. A cement floor if accessible may be used to advantage. The molds when in place are given a thin coating of soft soap, the platform or cement floor serving as bottom of mold being treated in the same way. About 1½ inches of concrete is spread evenly over the bottom and carefully tamped, so as to reduce it to a thickness of about 1 inch. A piece of board cut as in Fig. 7 will be found useful in leveling off the concrete to the desired thickness before tamping. On top of this layer two reinforcing members are placed about 1 inch from the sides of the mold. The molds are then filled and tamped in thin layers to the level of the other two reinforcing members, the fasteners for fence wires being inserted during the operation. These reinforcing members are adjusted as were the first two, and the remaining 1 inch of concrete tamped and leveled off, thus completing the post so far as molding is concerned. To avoid sharp edges which are easily chipped, triangular strips may be placed in the bottom of mold along the sides, and when the molds have been filled and tamped, similar strips may be inserted on top. The top edges may be beveled with a trowel or by running an edging tool having a triangular projection on its bottom along the edges. Such a tool is shown in Fig. 10 and can easily be made of wood or metal. It is not necessary to carry the level below the ground line.

The ends and sides of the mold may be removed after twenty-four hours, but the posts should not be handled for at least one week, during which time they must be well sprinkled several times daily and protected from sun and wind. The intermediate strips may be carefully withdrawn at the end of two or three days, but it is better to leave them in place until the posts are moved. Although a post may be hard and apparently strong when one week old, it will not attain its full strength in that length of time and must be handled with the utmost care to prevent injury. Carelessness in handling green posts frequently results in the formation of fine cracks, which, though unnoticed at the time, give evidence of their presence later in the failure of the post.

Posts should be allowed to cure for at least sixty days before being placed in the ground, and for this purpose it is recommended that when moved from the

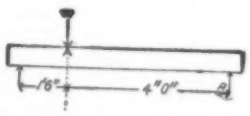


FIG. 11.—METHOD OF TESTING POSTS UNDER STATIC LOADS.

molding platform they be placed upon a smooth bed of moist sand and protected from the sun until thoroughly cured. During this period they should receive a thorough drenching at least once a day.

The life of the molds will depend upon the care with which they are handled. A coating of mineral oil or shellac may be used instead of soap to prevent the cement from sticking to the forms. As soon as the molds are removed they should be cleaned with a wire brush before being used again.

The cost of reinforced concrete fence posts depends in each case upon the cost of labor and materials, and must necessarily vary in different localities. An estimate in any particular case can be made as follows: One cubic yard of concrete will make 20 posts measuring 6 inches by 6 inches at bottom, 6 inches by 3 inches at top, and 7 feet long, and if mixed in the proportions 1—2½—5, requires approximately—

1.16 barrels of cement, at $2	$2.32
0.44 cubic yard of sand, at 75 cents	.33
0.88 cubic yard of gravel, at 75 cents	.66
Materials for 1 cubic yard concrete	$3.31
Concrete for one post	$0.17
28 feet of 0.16 inch steel wire, at 3 cents per pound	.06
Total cost of concrete and metal for one post	$0.23

To this must be added the cost of mixing concrete, molding and handling posts, and the cost of molds, an

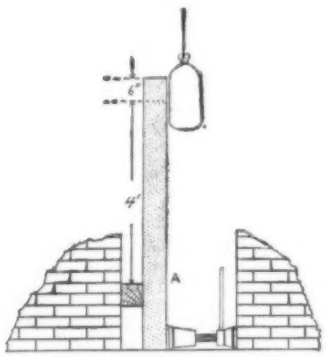


FIG. 12.—FIRST METHOD OF TESTING POSTS BY IMPACT.

addition which should not in any case exceed 7 cents, making a total of 30 cents per post.

CONCRETE BUILDING BLOCKS.

Concrete building blocks, or cement blocks, as they are frequently called, are more extensively used now than ever before. These blocks are molded hollow primarily to reduce their cost, but this hollow construction serves other useful purposes at the same time. The fundamental principles governing ordinary concrete work, so far as proportioning and mixing materials is concerned, apply equally well to the manufacture of building blocks, and it should be borne in mind that strength and durability can not be attained by the use of any machine unless the cement, sand, and aggregate are of good quality, properly proportioned, and well mixed. The aggregate for blocks of ordinary size should be crushed stone or gravel not larger than one-half inch. One of the chief causes of complaint against the concrete building block is its porosity, but this defect is in a great measure due to the fact that in an endeavor to economize, too little cement is frequently used. It is not unusual to give the blocks a facing of cement mortar consisting of about 2 parts sand to 1 of cement, while the body of the block is composed of a concrete of sufficient strength, though not impervious. This outside layer of mortar adds practically nothing to the strength of the block, and is used simply to give a uniform surface and to render the face of the wall more nearly impervious to water.

It would not be practicable as a rule to attempt the manufacture of concrete blocks without one of the many forms of molding machines designed for the purpose, nor would it be economical to purchase such a machine unless a sufficient number of blocks were required to justify such an outlay. Blocks in almost any desired shape and size, with either plain or ornamental faces, may be obtained on the market, and in the great majority of cases it is best to buy them from some reliable firm. Among the advantages claimed for hollow concrete block construction may be mentioned the following:

1. Hollow block construction introduces a saving of material over brick or stone masonry.

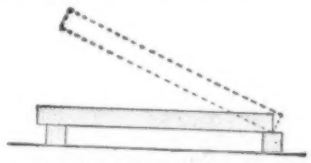


FIG. 13.—SECOND METHOD OF TESTING POSTS BY IMPACT.

2. The cost of laying concrete blocks is less than for brickwork. This is due to the fact that the blocks, being larger, require a much smaller number of joints and less mortar, and, being hollow, are of less weight than solid brickwork.

3. A wall constructed of good concrete blocks is as strong or stronger than a brick wall of equal thickness.

4. Concrete blocks, being easily molded to any desired form, will prove to be a far more economical building material than stone, which has to be dressed to shape.

5. Experience has proved concrete to be a most excellent fire-resisting material.

6. Concrete blocks, being hollow, tend to prevent sudden changes of temperature within a house, making it cool in summer and easily heated in winter.

7. The hollow spaces provide an easy means for running pipes and electric wires. These spaces may also be used wholly or in part for heating and ventilating flues.

APPENDIX.

Tests of Concrete Fence Posts.

In the summer of 1904 a number of reinforced concrete fence posts were made for experimental purposes, with a view to determining their adaptability for general use. These posts were made both with and with-

Table I.—Showing Resultts of Preliminary Tests of Reinforced Concrete Fence Posts.

No.	Kind of Reinforcement.	Per Cent of Reinforcement.	Mixture.	Material.	Span.	Load at First Crack.	Maximum Load.	Equivalent Load on Four-Foot Cantilever At First Crack.	Equivalent Maximum Load on Four-Foot Cantilever.
					ft. in.	lbs.	lbs.	lbs.	lbs.
1	No reinforcem't	....	1-3-5	Stone	4 0	1,435	1,435	359	359
12	"	....	1-3-5	"	4 0	670	670	168	168
20	"	....	1-3-7	Gravel	4 6	700	700	196	196
25	"	....	1-3-5	"	4 6	320	320	90	90
26	"	....	1-2-5	"	4 0	1,100	1,100	275	275
30	"	....	1-2-5	"	4 0	1,000	1,000	250	250
4	Plain steel rods.	0.27	1-3-5	Stone	4 0	1,580	1,850	395	463
17	"	.27	1-3-5	"	4 0	1,135	1,945	284	486
21	"	.27	1-3-5	"	4 6	920	1,600	258	473
24	"	.27	1-3-5	"	4 6	940	1,660	263	465
28	"	.27	1-3-5	"	4 6	900	1,730	224	432
35	"	.27	1-2-5	Gravel	4 0	1,100	1,650	275	388
36	"	.27	1-2-5	"	4 6	900	1,460	225	449
39	"	.27	1-2-5	"	4 0	1,340	1,640	335	410
40	"	.27	1-2-5	"	5 6	780	1,120	258	391
42	"	.27	1-2-5	"	4 6	1,100	1,290	308	361
44	"	.27	1-2-5	"	5 6	....	1,080	....	367
3	"	.52	1-3-5	Stone	4 0	1,800	2,520	450	630
7	"	.52	1-3-5	"	4 6	1,600	2,155	449	603
13	"	.52	1-3-5	"	4 0	1,640	2 500	410	625
15	"	.52	1-3-5	"	4 0	1,960	2,400	490	600
27	"	.52	1-3-5	"	4 0	1,680	2,220	420	555
45	"	.52	1-2-5	Gravel	5 6	980	1,800	313	612
46	"	.52	1-2-5	"	4 0	900	2,740	225	685
47	"	.52	1-2-5	"	4 6	1,000	2 450	280	686
50	"	.52	1-2-5	"	4 0	1,200	3 125	300	781
5	"	.81	1-3-5	Stone	4 0	2,640	4,800	660	1,200
10	"	.81	1-3-5	"	4 0	1,480	4,100	370	1,025
12	"	.81	1-3-5	"	4 6	1,980	4,100	521	1,148
14	"	.81	1-3-5	"	4 6	1,800	3,915	504	1,096
19	"	.81	1-3-5	"	4 0	1,800	4,160	450	1,040
22	"	.81	1-3-5	"	4 6	1,900	2,900	532	812
34	"	.81	1-2-5	Gravel	4 6	1,780	4,100	499	1,148
37	"	.81	1-2-5	"	4 0	1,500	3,545	375	886
43	"	.81	1-2-5	"	4 0	1,700	4,200	425	1,050
48	"	.81	1-2-5	"	4 6	1,240	3,575	347	1,001
6	"	.95	1-3-5	Stone	4 0	1,980	5,150	495	1,288
11	"	.95	1-3-5	"	4 6	2,380	4,300	666	1,204
18	"	.95	1-3-5	"	4 6	1,800	4,240	504	1,187
49	"	.95	1-2-5	Gravel	5 6	900	2,600	306	884
51	"	.95	1-2-5	"	4 6	1,380	3,160	386	885
52	"	.95	1-2-5	"	4 6	1,200	3,345	336	937
53	"	.95	1-2-5	"	4 0	1,340	3,840	335	960
54	"	.95	1-2-5	"	5 6	980	2,660	343	934
8	"	1.13	1-3-5	Stone	4 6	2,220	3,620	622	1,070
9	"	1.13	1-3-5	"	4 0	2,560	5,080	640	1,270
16	"	1.13	1-3-5	"	4 6	2,000	3,100	560	868
23	"	1.13	1-3-5	"	4 0	1,800	4,900	450	1,225
29	"	1.13	1-3-5	"	4 0	2,400	4,460	600	1,115
31	"	1.13	1-2-5	Gravel	4 6	1,500	2,900	420	812
33	"	1.13	1-2-5	"	4 0	1,400	2 330	350	580
38	"	1.13	1-2-5	"	4 6	1,500	3,270	420	916
41	"	1.13	1-2-5	"	4 6	1,250	4,300	350	1,204
55	Pipe 5 in. diam., ⅛ in. thick	1.10	1-2-5	"	4 6	1,800	4,000	504	1,120
56	"	1.10	1-2-5	"	4 6	1,720	4,000	482	1,120
57	"	1.10	1-2-5	"	4 6	.....	4,860	.....	1,305
58	□ 5 x 5 in., ⅛ in. thick	1.39	1-2-5	"	4 6	2,400	6,320	672	1,770
59	"	1.39	1-2-5	"	4 6	2,100	5.880	588	1,646
60	"	1.39	1-2-5	"	4 6	2,200	6,040	616	1,691
61	× 5 x 5 in., ⅛ in. thick	.98	1-3-5	Stone	4 6	1,100	2,480	308	694
62	"	.98	1-3-5	"	4 6	860	2,660	241	745
63	"	.98	1-3-5	"	4 6	1,800	2,400	504	672

Table II.—Showing the Strength of Reinforced Concrete Fence Posts.

No.	Kind of Reinforcement.	Total Sectional Area of Reinforcement.	Load at First Crack.	Maximum Load.	Equivalent Load on 4-Ft. Cantilever at First Crack.	Equivalent Maximum Load on 4-Ft. Cantilever.	Form of Reinforcement.
		sq.in.	lbs.	lbs.	lbs.	lbs.	
1	Drawn steel rods	0.06	800	1,120	218	306	
2	"	.06	820	1,145	224	313	
3	"	.06	640	1,080	175	295	
4	"	.06	795	1,040	217	284	
37	"	.06	940	1,170	257	319	
38	"	.06	740	1,075	202	293	
9	"	.19	1,140	1 280	311	349	
10	"	.19	1,170	1,885	319	515	
11	"	.19	1,020	1,950	278	532	
39	"	.19	760	1,945	207	531	
40	"	.19	820	1,925	224	526	
13	Twisted fence wire	.06	825	935	225	255	
15	"	.06	755	905	206	247	
16	"	.06	800	940	218	257	
17	"	.06	815	935	222	255	
18	"	.06	770	980	210	268	
19	"	.06	780	975	213	266	
21	"	.13	1,510	1,920	433	524	
22	"	.13	1,275	1 670	348	456	
23	"	.13	1,300	1,830	228	500	
24	"	.13	1,500	1,955	410	534	
25	Barbed wire	.06	980	980	268	268	
26	"	.06	820	820	224	224	
27	"	.06	590	740	161	202	
28	"	.06	745	745	203	203	
29	"	.06	590	590	161	161	
30	"	.06	550	640	150	175	
31	"	.06	560	635	153	173	
32	"	.06	480	530	131	145	
33	"	.13	680	1,040	186	284	
34	"	.13	840	1,010	229	276	
35	"	.13	1,280	1,515	349	414	
36	"	.13	800	1,375	218	375	
6	Drawn steel rods	.06	Tested by impact				
7	"	.19	"				
8	"	.19	"				
14	Twisted fence wire	.06					
20	"	.06	"				

* Reprint from Farmers' Bulletin, No. 235, issued by the Department of Agriculture.

out reinforcement, and tested at the age of 90 days. The reinforcement, ranging from 0.27 per cent to 1.13 per cent, consisted of four round steel rods, one in each corner of post about 1 inch from the surface, the posts having a uniform cross-section of 6 by 6 inches. The posts were molded in a horizontal position, as this was found by trial to be more satisfactory than molding them vertically.

The concrete was mixed moderately soft, crushed stone between 1 inch and one-fourth inch and gravel under three-fourths inch being used as aggregate. River sand, fairly clean and sharp, was employed with Portland cement. The posts were tested as beams supported at both ends and loaded at the center, with spans varying from 4 feet to 5 feet 6 inches. An attempt was made to prevent slipping by providing the reinforcing rods with collars and setscrews at the ends, but in every case, with but two exceptions, the rods slipped under a comparatively light load, thus showing the necessity for some form of mechanical bond. As would be expected, those posts which were not reinforced possessed very little strength.

A series of tests were made with sheet-iron reinforcement, in the form of round and square pipes, imbedded in the posts, but these posts, though developing considerable strength, proved less economical than those reinforced with plain rods, and at the same time were less simple in construction. The results of these tests, as recorded in Table I., do not properly represent the strength of similar posts in which some form of mechanical bond is provided to develop the full strength of the reinforcement.

In order to obtain more data on the subject, this investigation has been supplemented by a second series of tests, the results of which form the subject-matter for the sections on concrete fence posts and are expressed numerically in Table II.

In these tests it was decided to make the posts tapering in order to economize material and reduce their weight. For the concrete, Portland cement, river sand, and gravel were used in the proportion 1—2½—5, measured by volume, the gravel being screened below one-half inch. Sufficient water was used in mixing to produce a plastic mass, requiring only a moderate degree of tamping to bring water to the surface. The posts were molded, as previously described, kept under wet burlap for four weeks, and tested at the end of sixty days. The reinforcing members were placed in the corners of the posts about 1 inch from the surface, being looped and bent, as indicated in Table II. These posts were not designed with a view to developing the ultimate compressive strength of the concrete, but where greater strength is necessary it may be obtained at small expense by increasing the percentage of reinforcement. It is important that a fairly rich concrete should be used in all cases to enable the posts to stand exposure and to prevent chipping.

In these tests, as in those previously described, the object was to determine what transverse load, applied at a point 4 feet above the ground line, would be sufficient to crack the post, as well as the maximum load which could be sustained. Accordingly the posts were supported and loaded, as illustrated in Fig. 11, from which it is evident that the reaction at *R* represents the equivalent transverse load at the end of a 4-foot cantilever, corresponding to the applied load *W* at *A*, which is supposed to be the ground line, near which point failure occurred in every case except post No. 9, which sheared along the neutral axis. All of these posts measured 6 by 6 inches at the bottom and 6 by 3 inches at the top, except Nos. 29, 30, 31, 32, 33, and 34, which were 6 by 6 inches at the bottom and 3 by 3 inches at the top. It will be noticed that the saving in concrete introduced in the construction of these posts is accompanied by a marked decrease in strength as compared with the other posts similarly reinforced. It would also appear that the twisted wire has a slight advantage over the barbed wire as a reinforcing material, particularly when two wires are used in each corner of the post.

As stated, it is impracticable to make a reinforced concrete fence post as strong as a wooden post of the same size, and this is more especially true if the post has to withstand the force of a sudden blow or impact. In order to study the behavior of these posts under impact, a number of them were braced, as illustrated in Fig. 12, and subjected to the blows of a 50-pound bag of gravel, suspended from above by a 9-foot rope. The first blow was delivered by deflecting the bag so as to give it a vertical drop of 1 foot, and for each successive blow the drop was increased 1 foot. None of the posts showed any sign of failure under the first blow. Posts Nos. 14 and 20 cracked under the second blow, and failed under the third. Post No. 6 cracked under the second blow, which crack opened under the third blow, causing a momentary deflection of 5 inches. Posts Nos. 7 and 8 each developed a crack under the second blow, but showed no further signs of weakness after the fifth blow, other than a slight opening of the initial crack. In each case the only crack developed was at point *A*. Posts 6, 7, and 8, which cracked but did not fail under the impact test, were further tested, as indicated in Fig. 13, by raising the small end and allowing them to drop from successive heights at 1, 2, 3, and 4 feet. Under this test a number of cracks developed, but in no case did the reinforcement fail.

Although it might appear from these results that posts as here described have hardly enough strength to recommend them for general use, it should be remembered that in many cases fence posts are not subjected to impact, and it may prove more economical to replace from time to time those which fail in this way than to use wooden posts, which, being subject to decay, must all be replaced sooner or later.

Retempering.

Table III. illustrates the effect of retempering Portland cement mortar. The mortars used consisted of Portland cement and crushed quartzite between one and two millimeters in size, mixed in different proportions. In each case, after the initial or final set had taken place, sufficient water was added in retempering to restore normal consistency. The briquettes were tested at the age of four months.

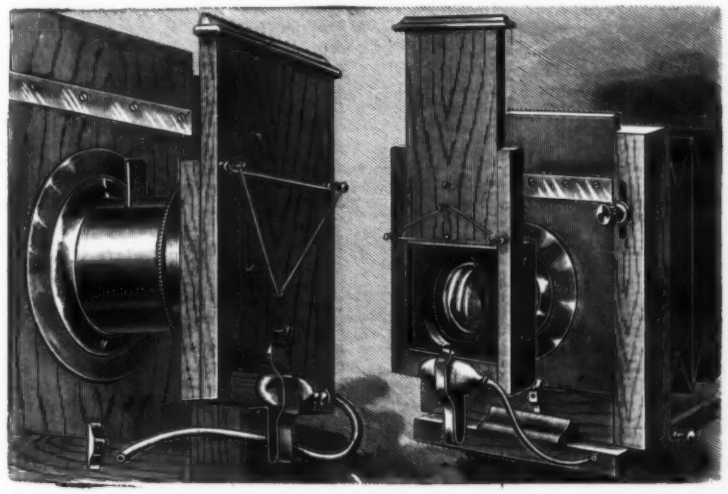
Table III.—Effect of Retempering on Cement Mortars.

Treatment of Mortar.	Tensile Strength, in Lbs., per Sq. Inch			
	Neat Cement.*	1 Part Cement, 1 Part Sand.†	1 Part Cement, 2 Parts Sand.‡	1 Part Cement, 3 Parts Sand.‖
Mortar made up into briquettes immediately after mixing	651	624	527	417
	660	701	493	385
	673	624	629	421
	634	581	480	403
	679	610	492	409
Average	657	628	504	407
Mortar allowed to take initial set, then broken up and made into briquettes	671	692	589	326
	593	670	554	349
	644	654	559	330
	633	676	534	358
	724	700	532	297
Average	653	678	554	336
Mortar allowed to take final set, then broken up and made into briquettes	455	527	492	304
	522	569	491	320
	525	587	497	361
	558	566	486	315
	642	568	531	345
Average	540	563	499	353

* Initial set, 1 hour 42 minutes; final set, 7 hours 15 minutes.
† Initial set, 1 hour 30 minutes; final set, 7 hours 15 minutes.
‡ Initial set, 2 hours; final set, 7 hours.
‖ Initial set, 2 hours 30 minutes; final set, 7 hours.

A SIMPLE CAMERA SHUTTER.

IT would be difficult to say who invented the simple shutter shown in the annexed engraving. It has been made and used by amateur photographers, and seems to answer the purpose very well indeed. Although it is crude when compared with some of the perfected shutters, the results secured by it are not inferior to those of better instruments.



HOME-MADE CAMERA SHUTTER.

The block forming the support for the working parts is bored to receive the outer end of the camera tube. To this are attached two grooved uprights and a cleat extending across the block at its lower edge To the grooves of the uprights is fitted the shutter, which consists of a piece of thin board blackened on its inner surface, and provided on its outer surface with three escutcheon pins, all arranged on the median line of the shutter. The lower pin, which is without a head, is engaged by a spring catch. The second pin projects the farthest, while the third projects only a short distance. In each grooved side strip is inserted a pin, which projects some distance from the surface of the strip. An ordinary rubber band is stretched around these pins, and the outer strand is wound several times around each pin, to separate it from the inner strand. The spring catch, which is attached to the bottom of the block is bent outwardly to permit of placing under it a small pneumatic bulb similar to those used on pen fillers. With the bulb is connected a flexible rubber tube, having on its free end a larger bulb, by means of which the smaller bulb is inflated when the shutter is to be released.

The shutter is held normally in a closed position by the spring catch, which engages the lower pin. In another form of the shutter an ordinary hook is used in lieu of the spring and pneumatic bulb.

To prepare the shutter for operation, the outer strand of the rubber band is placed around the upper and shorter pin, as shown in the left-hand figure. When the exposure is to be made, the shutter is operated by compressing the large bulb, which inflates the smaller bulb, thus pressing outwardly the spring catch and disconnecting it from the pin. The elasticity of the rubber band forces the shutter upward until the pin passes above the inner strand of the rubber band. The momentum of the shutter carries it upward, and bringing the longer pin into engagement with the inner strand of the rubber band, stretches the band, as shown in the right-hand figure, thus arresting the movement of the shutter and storing power for closing it. The elasticity of the inner strand of the rubber band is sufficient to cause the shutter to drop quickly and regain its original position.

RECENT ADVANCES IN WIRELESS TELEGRAPHY.*

By J. ERSKINE-MURRAY, D.Sc., Member.

I. INTRODUCTORY.

As this paper does not deal with the history of wireless telegraphy, I do not propose to discuss the many systems which have paved the way for those that are now in use. The work of Morse, Lindsay, Willoughby Smith, Hughes, Preece, and many others is of great interest, but except in the last case their systems are no longer in use. I shall not attempt to give details of the many forms of apparatus which in principle resemble Mr. Marconi's instruments, merely contenting myself with giving a brief description of the more typical patterns. Accounts of the systems of Popoff of the Russian navy, of Dolbear, of Edison, of Tesla, and of Armstrong and Orling have been published, and may be studied by those interested. In our own navy, Capt. H. B. Jackson had already invented a practical system when Mr. Marconi commenced work in this country, but for obvious reasons it was never described in print. We shall confine ourselves, then, to the consideration of some typical systems, and in particular to those which are in most general use.

II. THE CHIEF SYSTEMS IN USE.

It is hardly necessary to say that the system, until quite recently, in most general use throughout the world is Marconi's untuned aerial with earth connection; an induction coil and spark gap being used in the transmitter and a coherer in the receiver. Other non-discriminating systems differ in name and in certain details, but the general principle is the same.

When we come to tuned or discriminating systems the case is different; many of them appear to differ essentially from one another in general arrangement as well as in detail; some use high voltages, and others long trains of waves of comparatively low voltage; some are earthed conductively and others inductively, while the receivers differ in principle and often contain no coherer.

A brief description of the more important systems is necessary in order that the lines on which progress is being made may be grasped. It will be understood that a full account, even of the more important systems, cannot be attempted in the present paper, when it is stated that nearly three hundred British patents relating to wireless telegraphy have been granted, many of them claiming to be for complete systems. Among these it is natural to commence with that which has been longest in practical use, viz., Marconi's untuned, coherer system. It has been in use commercially on board a large number of passenger ships, and with certain variations and under many names appears to be the common system in most of the navies of the world. No doubt, untuned systems are being displaced by tuned systems, but their comparative simplicity and ease in working are recommendations which in many cases outweigh their disadvantages.

Marconi's untuned system is mainly used for distances under a hundred and fifty miles, and in the following description the assumption will be made that the distance does not exceed this limit; the reason for this limitation being that at such distances the lines of force from the charge on the aerial wire have time to reach the receiving station before the spark occurs at the transmitter. Under these circumstances an electrostatic charge suddenly discharged with or without oscillations is thus all that is necessary.

In ordinary wire telegraphy the electrical impulse travels through the air, or other insulation surrounding the wire, from the transmitter to the receiver, pro-

* Read before the Institution of Electrical Engineers.

ducing as it goes a current in the wire and actuating the receiving instrument. The wire is only a conductor, that is to say, it guides the electrical energy from one station to the other. In Marconi's aerial wire system, the surface of the earth or sea takes the place of the conducting wire of wire telegraphy; the impulse spreads out all around the sending station, and affects any properly-constructed receiver placed within a distance which depends on its sensitiveness and on the power of the transmitter. Now, as the impulse spreads out all around, only a small fraction of it reaches the receiving station, hence it is necessary that it should be more forcible than that employed in transmission of signals along wires. This is effected, as a rule, by charging the aerial conductor to a high electrical pressure, by connecting it to one terminal of an induction coil or transformer, and allowing the charge to rush suddenly to earth as a spark across an air-gap a centimeter or two in length.

About fifty sparks occur each second, and each spark lasts not more than a hundred-thousandth part of a second. Thus the horse-power of a discharge is about two thousand times that of the current supplied to the induction coil. As the latter is usually about 50 watts, each impulse sent out works, for a very short time, at two or three hundred horse-power. Thus, even if the receiver be at a considerable distance, the fraction of the impulse which reaches it is quite appreciable. No ordinary telegraph instrument, however, is able to detect a current which lasts for so short a time, hence the necessity for the coherer, which does.

What happens, then, in the sending of a signal is as follows:

(1) The aerial wire is charged, say, positively, and lines of electric force spread out from it having their negative ends on the earth surface all round, some of them ending on the aerial wire of the distant receiver. (2) When the electrical pressure has become so great that the spark jumps across the gap between the aerial and the earth wire, there is a sudden change in the distribution of the electricity. The negative spread out over the earth or sea and on the aerial of the receiver, rushes in toward the positive, producing a current of quite appreciable voltage, though of very short duration. It is this current which actuates the receiver in passing through it from the aerial wire to the earth.

In practice, the operator makes the primary circuit of the induction coil in the transmitter, the aerial becomes charged, then discharges itself and one dot is sent. If he continues to hold the key down, the break, or interrupter, on the coil continues to vibrate, and a series of dots in rapid succession is sent, which is recorded as a dash by the receiver.

The first impulse is no doubt followed by a very short train of rapidly-decreasing waves; but the decrease is so rapid that they are of but little use in transmission. The coefficient of damping, experimentally determined, is about 0.6; i. e., the amplitude of the second wave is 0.6 of that of the first, while the third wave has only an amplitude of 0.36, and the fourth of 0.21. The frequency in this case was found to be approximately 500,000. The decay is thus very rapid, and the transmission of signals depends almost entirely on the first wave. Since these determinations were made Prof. Fleming has designed an instrument, which he calls a cymometer, for measuring frequency and wave length. A circuit, containing an inductance and a capacity which may be simultaneously varied, is placed near the circuit whose frequency is required. The capacity and inductance are then altered until equifrequency, and therefore resonance, is obtained, which is indicated by a vacuum tube lighting up in the cymometer circuit. This instrument should prove very useful for many purposes in wireless telegraphy.

There was little hope of preventing interference between neighboring instruments as long as the first impulse predominated so very strongly and was capable of actuating any receiver by itself.

The methods of discrimination or tuning now employed in almost all systems depend on the principle of the superposition of small motions. When one child swings another in a swing it gives a series of little pushes, each one being timed to the time of the swing. The swing goes higher at every push, and in the end is swinging more energetically than even a strong man could have accomplished with a single effort. But if the pushes were not properly timed the swing would never attain to motion through a large arc, as some would check while others increased it.

The electrical resonance of two systems of conductors whose natural electrical vibrations are equifrequent may be illustrated mechanically by a simple experiment. The bobs of two heavy pendulums are connected by means of a very fine thread of India rubber. One of the pendulums is set in motion. If the natural frequency of the second be the same as that of the first, it will very soon be swinging through a considerable arc. If its length, and hence its frequency, be different, it will remain practically at rest.

In wireless telegraphy, tuned systems, and, indeed, long distance transmission in general, depend on this phenomenon. The moving masses are masses of electricity, and the dimensions regulating their frequency of oscillation are the inductance, capacity, and resistance of the circuit in which they move. Thus, if a series of small electrical impulses or waves arrive at a receiving station, each impulse being timed so as always to increase the motion of electricity in the receiving conductors, an oscillatory current will be generated of rapily-increasing amplitude, which stores up the energy arriving until the current becomes great enough to actuate the receiving mechanism. The most obvious application of this principle to telegraphy is the discrimination between a group of sending and receiving stations by giving the members of each pair, which are intended to communicate, the same electrical dimensions, so that a transmitter, and the receiver it is intended to communicate with, have the same natural frequency. This plan has been adopted by almost all inventors, and works well.

In 1889 two different messages from separate transmitting stations were simultaneously received without confusion by Mr. Marconi at South Foreland on receivers suitably constructed. This was, I believe, the first ocasion on which such discrimination was carried out on a large scale.*

The principle has been wonderfully developed since then, the most strikingly successful result being that obtained by Capt. Jackson, R. N., who this year, while receiving messages from a ship at a moderate distance on the mainmast of H. M. S. "Vernon," was simultaneously transmitting messages from the foremast to another vessel 500 miles off. It is truly marvellous that the tremendous electrical disturbance radiating from one end of the "Vernon" in no way affected the receiver only a few yards removed from it, and the achievement must be recorded as a great triumph of experimental science.

This result was rendered possible by an alteration in the original Marconi receiver, which, though apparently small in itself, was of far-reaching importance. In the old receiver the coherer formed a gap of enormously high resistance between the aerial and earth wires which effectually prevented any oscillation in the receiver except the small current which might occur through the coherer plugs acting as a condenser. The coherer was simply cohered by the voltage produced in the aerial, as described in section 4. In the new receiver the aerial wire was connected to earth through the primary of a small transformer, thus providing a path of low resistance in which oscillations could grow in amplitude as the impulses from the transmitter arrived, and a secondary circuit which could be made exactly equifrequent with the oscillations arriving from the distant station.

Curiously enough, this transformer, or jigger, as it is usually called, was originally introduced to prevent the accumulation of atmospheric electricity on the aerial wire and not for purposes of tuning. It served both purposes, however, and rendered discrimination practicable, while at the same time it enormously increased the distance over which transmission could take place, by utilizing the energy of all the waves arriving instead of only that of the first. The transmitter was next improved by the introduction of more capacity and inductance, enabling it to give out a much longer train of waves, of which, perhaps, thirty or forty are of useful amplitude, instead of two or three in the earlier form.

In almost all modern tuned systems the oscillations are generated in a separate circuit by Tesla's method, and are impressed upon the transmitting aerial either by induction or conduction, the method of connection being called the "coupling," which is said to be strong or weak, according as as much or little of the Tesla circuit is included in the aerial. This method produces a longer train of waves than was practicable where the aerial system was the only oscillating circuit, and enables one to make a more exact adjustment of the frequency, thus giving both greater distances and a greater certainty of discrimination between stations which might interfere. Most modern patents are improvements in this direction. We must now consider in greater detail a few of those in use.

One of the first patents for a syntonic or discriminating system was that taken out by Prof. Lodge in 1897. The transmitter was practically a Hertz radiator on a large scale with some inductance introduced, i.e., two equal conductors placed one above the other in a vertical line with a spark gap between them, the connection to the spark gap being through a few turns of thick wire. Similar conductors were used for receiving, but in place of the spark gap was introduced the primary of a small transformer, the secondary of which was in the coherer circuit. In a somewhat modified form this apparatus has been installed at Heysham by the Midland Railway for communication across the Irish Channel. In this case two large horizontal surfaces of conductor about 80 feet square are placed, one at about 3 feet above the ground and insulated from it, and the other 80 feet above the first. Wires reach upward from the lower sheet and downward from the upper to the spark gap. This forms a very persistent oscillator, and at first sight would appear to radiate free Hertzian waves. I shall show, however, later that, like all other practical wireless systems, it has in reality an excellent earth connection, which is obtained in this case by induction.

In another type of Lodge-Muirhead transmitter, the lower end of the aerial is connected to a condenser, which, in turn, is conductively earthed through a wire having some inductance. The aerial of the receiver is connected conductively to earth through the primary of a jigger. The coherer is a small, rotating steel disk, the lower edge of which dips into mercury covered with a film of oil. Its advantages are its automatic decoherence and its low resistance when cohered. The receiver circuit contains the secondary of the jigger, the coherer, and a condenser in series; while a siphon recorder and a source of current are in parallel with the condenser. This form has been used for military signaling, and other purposes.

Mr. Marconi, early in 1900, invented a discriminating system which apparently has great possibilities both in regard to exact tuning and to reduction in height of aerial. In fact, signals were received over a distance of thirty miles with an apparatus only about four feet high.

Its action is as follows: The metal cans form a condenser which is charged by the induction coil: the discharge then takes place across the spark gap, oscillating a large number of times owing to the considerable inductance and capacity in the circuit: a portion of the oscillating current is transmitted to the earth by the earth wire, since this wire is connected to a point of the circuit at which there is considerable variation of the potential during each oscillation. It is this unsymmetrical position of the earth coupling which renders transmission of energy possible. The receiver is exactly similar to the transmitter, the primary of the jigger taking the place of the spark gap.

There is a very large number of ways in which one or two condensers and inductances may be combined with an earth and air wire to form an oscillating circuit. Transmitters of this kind, however, may broadly be divided into two classes, firstly, those in which the natural oscillation frequency of the aerial wire is utilized, and, secondly, systems in which the oscillation in the aerial is a forced one, its frequency being determined by a very persistently oscillating circuit coupled to the aerial. This latter method is becoming more and more general, as it is much more easy to obtain the persistent oscillations necessary for sharp tuning in a closed circuit than in the "open" circuit, partly conductor and partly dielectric, formed by the aerial and the earth.

For long-distance telegraphy, many ingenious improvements in methods of transmission have recently been devised which relate mainly to the production of long trains of powerful waves in the transmitter, and to the use of several oscillating circuits of the same frequency coupled to one another in series in the receiver, thus obtaining a system which responds only to a wave train of exactly the same frequency.

The more important improvements in long-distance work are due mainly to Mr. Marconi and to Prof. Fessenden. Mr. Marconi maintains regular communication between England and Italy, a distance of about a thousand miles, mostly overland, and has, of course, frequently achieved greater distances, including the whole width of the Atlantic. Mr. Fessenden has maintained communication over six hundred miles, and is now putting up a transatlantic station at Machrihanish by means of which it is hoped to communicate with the United States. The De Forest Company have also arranged to put up a transatlantic station at Tiree.

At Poldhu and in his other transatlantic stations, the most recent being that in course of erection near Roundstone, County Galway, Mr. Marconi employs a large number of aerial wires, arranged like an inverted pyramid, all being connected at the vertex to the generating circuit and to earth. A very large electrified surface and capacity is thus obtained with the use of a very moderate quantity of conductor. At the same time the electric lines of force commence at a considerable elevation above the earth, thus facilitating their wide distribution and insuring a sufficiently long wave length. The wires are spread out, which gives a free path for the lines of force from earth to earth, giving practically a greater capacity to the system than if they were bunched together, in which case the inner wires of the bunch would be nearly useless. The generating system contains a Tesla circuit operated by an alternator and coupled to the aerial. The receiver generally used for long distances is the form of magnetic detector, based on Rutherford's experiments and designed by Mr. Marconi. It consists of a small transformer with an iron core, near which a permanent magnet is kept in motion. Thus the magnetization of the wire is continually going through a series of cycles. The primary is connected to the aerial and earth wires, while a telephone is placed in the secondary circuit. The explanation given of its action is that the oscillatory currents in the primary, received from the distant station, cause an alteration in the hysteresis of the core, and, as a consequence, the alternating current induced by the motion of the permanent magnet is altered, and a variation produced in the indications of the telephone. This receiver is very sensitive, and as it contains a completely closed circuit, should be susceptible of very accurate tuning leading to a further increase of sensibility.

Mr. Fessenden uses a single aerial conductor: a great sheet-iron tube like a factory chimney about 420 feet high. Long trains of waves of what may, for wireless telegraphy, be called low voltage, are transmitted, and receiver and transmitter have frequencies which are very exactly equalized. Fessenden's receiver contains, instead of the coherer, a device called a barreter, which in its original form is a closed metallic circuit, a small part of which is of extremely fine wire. The oscillations between the receiving aerial and earth pass through a transformer to the barreter circuit, the oscillating currents warm the fine wire, and therefore alter its resistance. The fine wire forms one arm of a Wheatstone bridge, hence any change in its resistance causes a deflection of the galvanometer or siphon recorder. The advantage claimed for this type of responder is that, being a continuous conducting circuit, it allows of the gradual growth of oscillating currents in the receiver, and thus renders resonance more easy.

In a later form, however, a fine point of platinum in an electrolyte is used; practically the original barreter with a minute break in the wire. The action is now not merely that of a metal conductor, but may be either due to the starting of a very minute arc by the oscillations, as an arc lamp with its carbons apart may

* Sir Oliver Lodge had previously patented a syntonic system, but I know of no earlier record of its achievements.

be started by a spark of high potential; or, perhaps, more likely to an action of the oscillations on the polarized surfaces in the electrolyte, such as has been recently (Faraday Society, October 31, 1905) investigated by Prof. E. Wilson and Mr. W. R. Cooper. It is possible that the oscillations are themselves rectified and thus added to the current in the local circuit. Many years ago Mr. Shelford Bidwell discovered that certain electrolytic cells are sensitive to light and other disturbances.

The transmitter to be used for transatlantic work is apparently that most recently patented by Mr. Fessenden. It is practically an alternator with one terminal connected to the aerial and the other to earth. Possibly other circuits may be introduced, but no information has so far been published. The advantage of this transmitter is that an indefinitely long train of waves of equal amplitude may be emitted. If the receiver be exactly equifrequent, the energy of each wave may be very small as their effect is cumulative.

Another patent of Mr. Fessenden's describes a system in which two trains of waves of different frequency are transmitted by one aerial, the receiver being only actuated when waves of both frequencies are simultaneously received. This system opens up great possibilities in regard to discrimination between different stations, as the combinations of two variable quantities, i. e., the frequencies of both sets of oscillations, are involved instead of only the frequency of one set. A similar system has been patented by Braun.

Sir William Preece's electro-magnetic system is in use between Rathlinn Island and the north coast of Ireland.

Among other systems in commercial use the De Forest, Popoff, Slaby-Arco, and Braun may be mentioned. The Slaby-Arco aerial is in the form of an arch having two earth connections. The others somewhat resemble the Marconi system.

III. MORE RECENT SYSTEMS.

Many patents for complete systems and for improvements have been taken out in the past two or three years. Few, if any of them, are as yet in commercial use, but it is necessary to give a brief notice of some of those that seem sufficiently original to lead possibly to practical development in competition with the more established systems. One of these is Artom's system of polarized waves. Two separate aerials, which together form a St. Andrew's cross, are set up. They are insulated from one another and connected to earth through generators which give oscillating currents differing in phase. A circularly-polarized wave is thus sent out in a line perpendicular to the plane of the cross. The idea is that this wave will retain its form and will travel mainly in one line, i. e., toward the receiving aerials. These are similar to those of the transmitter. The receiver is only actuated when oscillations with the proper phase difference between them take place in both aerials. In a more recent system on the same plan, the inventor uses three aerials with angles of 60 deg. between them. It is somewhat doubtful whether at long distances the polarized waves may not become seriously distorted by the earth's action as a conductor. At short distances, however, the arrangement seems a feasible one, and may provide a useful means of discrimination between various stations.

Maskelyne has taken out patents for systems in which aerials in the form of arches or triangles are used, condensers being inserted at the lower ends to make connection with the generator or the receiver. His experiments have been successful on a practical scale.

Marconi has patented a system in which a U-shaped aerial formed of two wires connected at the bottom by an inductance and spark-gap is used. An earth connection is made to one side of the U. This arrangement gives a much longer train of waves than a simple aerial, and is thus susceptible of tuning.

Blondel has patented a somewhat similar arrangement of two aerials, the distance in this case between the aerials being regulated to the wave length and phase of the oscillations, so that they interfere and annul one another in a vertical plane through the wires. Thus transmission mainly takes place at right angles to the plane of the aerials.

Other patented systems are mainly based on well-known types, slight variations being introduced in detail, while some involve circuits so complicated as almost to defy explanation. It is not likely that many of them will come into practical use.

IV. THE ACTION OF THE COHERER.

The coherence of metal filings or surfaces was supposed at first to be due to electrical oscillations, and to be a test for their presence. I have never held the view that oscillations were necessary, believing that all that is required is merely an electrostatic field or difference of potential which causes the particles to join up in chains as do iron particles in a magnetic field.

That small particles do so in an electrostatic field has been shown by Robertson and others. When the ends of the particles come within a very small distance of one another a spark passes even if the voltage be low, and the welding takes place. The action is facilitated by very gentle intermittent mechanical shocks (rapping) just as in the case of iron filings in a magnetic field. Severe shaking, of course, prevents any chains from forming, or breaks up such as have been formed.

The action of a filings coherer thus takes place in two stages—first, the movements of the particles, and second, the welding.

That this view is correct has been amply proved by Dr. W. H. Eccles in an able experiment research which he undertook at my suggestion. He has also deduced a mathematical theory of the action which fits the results of experiment, and invented a method for testing coherers in the laboratory without the use of telegraphic apparatus.

V. TRANSMITTERS.

The main essential in wireless telegraphy is that the transmitter must cause a difference of potential at two ends of the receiving apparatus sufficient to cause an appreciable current to flow for however short a time through it. In most modern systems the current in the receiving apparatus flows to or from what might be called the dead end of a conductor were it not for the fact that it is very much alive. The circuit is, in fact, completed by the dielectric (the atmosphere), and, in a circuit such as this, though a continuous current is impossible, an alternating one may, of course, exist and convey energy. Now the maximum potential received is definite, owing to the methods of producing it in the transmitter; it follows that the amount of electricity made to move in the receiver by the first impulse from the transmitter is also fixed, since the possible change depends on the voltage and capacity of the receiving conducting system. Now the quantity of electricity thus being limited, it is clear that the more rapid its motion the larger its current. Thus, if a maximum value of the potential difference arriving at the receiver be, say one volt, it is all-important that its rate of change should be great. If it takes a comparatively long time, all the electricity movable under the circumstances may flow gently through the receiver as a very small current which does not actuate the receiver. If, on the other hand, the potential rises rapidly to its maximum, the electricity will not have had time to move appreciably before the maximum voltage is attained, and thus the current will be very much greater, though, of course, of less duration.

A comparatively short period and wave length is thus advantageous if but little power is available. This is realized in Hertz's radiator, which is charged comparatively slowly by an induction coil, and then discharges itself with extreme rapidity when the voltage has risen sufficiently to cause a spark across the gap between the conductors. The current in the radiator oscillates with very high frequency, and dies out in a very short time. The emitted waves are thus of great energy while they last. In the systems most in use at present the method of obtaining this sudden and energetic discharge is that of the Hertz, i. e., the spark. It is Hertz's method of obtaining a sudden and oscillating discharge that is the essential in wireless telegraphy, not the fact that free radiations may be produced thereby. An alternator would be quite as suitable if it were capable of giving the voltage and frequency, and, indeed, is being used by Fessenden.

Modern wireless telegraphy is not true radiation, and in the systems now in use direct radiation is a dead loss; nor is it exactly space telegraphy, for this term seems to indicate a course independent of the earth; a course which, owing to the curvature of the earth, leads straight into outer darkness. True Hertzian waves, i. e., electric waves travelling unguided through space, have been used for telegraphs only to a maximum distance of a mile or two. One might almost as well try transatlantic telegraphy with a searchlight as with these.

When Marconi connected the lower ball of his Hertz radiator to the earth, he made the whole earth the lower ball. The earth and the aerial are the two conductors of the oscillator, which luckily is so unsymmetrical that it radiates very little indeed; in fact, the oscillations simply spread from their point of generation over the two conductors.

Remember direct radiation is dead loss in wireless telegraphy, since it means waves going straight off into space and not following round the curve of the earth to their destination on this globe. Messages to or from Mars might be very interesting, but as yet they are not within the range of commercial telegraphic business, or even of practical politics.

VI. EARTH CONNECTIONS.

When Marconi connected his Hertzian radiator to the earth he at once obtained signals at a much greater distance than he had previously achieved. He had, in fact, introduced a conducting connection between the transmitter and receiver, instead of depending on radiations through the non-conducting atmosphere. The electrical waves produced were no longer free, but were guided by the earth's surface as an alternating current is guided by a wire.

For the intense currents of very high frequency, which are used in wireless telegraphy, a good and widespread earth-connection is most essential. It is not necessary that it should be a conducting connection, however; an inductive connection, in which the earth's surface plays the part of one plate of a condenser, is quite as effective for high frequency currents.

Wireless telegraphs may thus be divided into two large classes—(1) conductively earthed (2) inductively earthed.

In the first class come practically all the systems mentioned except some forms of Lodge Muirhead apparatus.

To improve the earthing, Fessenden uses a large number of thick wires radiating from the lower end of the transmitter to earth plates at some little distance. He calls this arrangement a wave chute.

In the Lodge-Muirhead station at Heysham the earthing is inductive. One large insulated plate is about 3 feet above the earth, the other plate is 80 feet above the first.

Taking the average difference of potential between the earth's surface and the lower plate as roughly one-half of that between the plates, we find that the dielectric current between the earth and lower plate is ten times as great as it would be through the spark gap between the plates if the earth were not near. A conduction current in the earth's surface is thus induced by the proximity of the lower plate, and the waves are guided by the earth's surface as in conductively earthed systems. Radiations approximately resembling on a large scale those used by Hertz, would not be obtained by this transmitter unless it were placed at least 800 feet or more above the earth's surface on a perfectly insulating support.

If Hertz had placed one end of his vertical oscillator within a small fraction of an inch of a horizontal sheet of copper, he would not have obtained free radiations, but a result which on the proper scale would resemble the transmission at Heysham.

As it is, it seems probable that the inductive earthing in this case will prove as effective as an elaborate conductive system, and at the same time the advantages of a very persistent oscillator will be retained.

VII. THE LIMIT OF DISTANCE IN TRANSMISSION.

The propagation of a hemispherical electric wave, in which the lines of force have their ends on a conducting plane surface has been investigated by Heaviside, and from a wireless telegraphist's point of view by Blondel. Neglecting the curvature of the earth, the form of the wave is approximately the same as would be produced by removing the earth and putting another wire downward from the spark gap, this wire being equal in length to the aerial, and oppositely charged at every moment. If the electric waves used in wireless telegraphy retained this form we should find that the currents resulting from their action on the receiving aerial would vary inversely as the square of the distance. This does not, however, agree with Duddell and Taylor's measurements—the only definite measurements as yet published—of the variation of the received current with distance. They find* from experiments made between a station at Howth and H.M. T.S. "Monarch" in the Irish Channel, that the current at distances beyond ten or fifteen miles varies in almost exactly simple inverse proportion to the distance between the stations. This result admits of no question, the experiments having been carried out most carefully and with wonderfully concordant results. We must, therefore, accept the fact and look for an explanation in some circumstance which modifies the hemispherical waves originally given out by the transmitter when they attain a radius of about ten miles.

I find that there is an explanation lying ready to our hand, which is based, not upon theory, but on the well-ascertained facts of the nature of our atmosphere. Put briefly, it is as follows: If the earth were surrounded by a spherical shell of conducting material it is a well-known fact that the waves would not die away in proportion to the square of the distance, but would vary, for moderate distances in inverse proportion to the distance itself. Now, recent researches on auroræ by Danish observers have proved that these occur sometimes as low as six miles above the earth's surface, and never at a greater height than sixty miles. An aurora is an electric conduction current; hence the layer of air between six and sixty miles above the earth is conducive.

Here we have, then, the explanation of Duddell's law of variation with distance. The approximately spherical wave given out by the oscillator rises till it touches the conducting layer, then becomes annular, and travels outward with a wave-front, the area of which no longer increases as the square of the distance, but only in proportion to the distance itself, since the wave is confined by the parallel conducting surfaces above and below. Thus the only space variation which causes diminution in strength is the increasing radius. There is, of course, in addition a frictional loss of energy which we shall consider later.

If we take the curvature of the earth into account, and proceed to trace the variation of the wave-front at greater distances than those of Duddell's experiments, which only extended to sixty miles, we find from simple mathematical, or rather geographical, considerations that the radius of the circle in which the wave-front cuts the globe is directly proportional to the sine of the angle at the earth's center subtended by the arc of the surface between the transmitter and the wave-front. This agrees with Duddell's law because for small distances $\sin\theta$ is nearly equal to θ. For greater distances, however, the divergence becomes less and less, and at distances beyond 6,000 miles, i. e., beyond $\theta = \pi/2$, the waves converge, and the current should increase with distance. This is true on any theory, as the wave-front is becoming a smaller and smaller ring, continually converging from all sides toward the antipodes of the transmitting station.

The equation for the received current is thus of the form:

$$c = \frac{C}{\sin\theta} \qquad (A)$$

where c is the received current, θ the angle defined above, and C a constant.

The above law of variation of the received current with distance is obviously not complete. We have so far supposed that the lowest layer of the atmosphere is a perfect dielectric, and that the earth and upper atmosphere are perfect conductors, i. e., that no dissipation of energy is involved, the decrease of current being simply due to increase in area of the wave-front.

We must now take account of frictional losses, in order to complete the law as far as possible; though with the date at present available only a rough approximation can be attempted. It will be possible to

* Journal of the Institution of Electrical Engineers, July, 1905.

amplify the equation when further measurements have been made, and to determine more exactly the functions and constants involved.

The first indication of a true frictional dissipation of energy in transmission was found in Mr. Marconi's discovery that messages could be received at much greater distances during the night than by day. There cannot be much difference between the divergence variations by night and day, as the earth does not change its shape; this phenomenon has, therefore, to be explained by some difference in the electrical properties of the transmitting media. Now the conductivity of the earth cannot be seriously altered by the sun's rays; the atmosphere, however, may be much affected. Cosmical science has made many striking advances lately, and it is now practically certain that streams of electrified particles, resembling the cathode rays, are ejected from the sun with a very high velocity. These penetrate the earth's atmosphere on the day side, electrifying it, and at the same time ionizing it, thus rendering it more conductive. During the night equilibrium becomes slowly restored, and toward five o'clock in the morning a very marked minimum of atmospheric electrification has long been known to exist. The time at which signals go furthest thus coincides with a minimum conductivity of the lower layers of the atmosphere while greater conductivity of the lower layers during the daytime coincides with greater difficulty in transmission.

HARVARD'S BOTANIC GARDEN.*

By MARY CAROLINE CRAWFORD.

THAT increasing army of pilgrims who each summer return to New England to enjoy the delightful excursions for which Boston offers a natural geographical center will, this year especially, wish to include in their itinerary a day at the Harvard Botanic Garden, inasmuch as 1905 marked the centenary of this noble institution's conception. The occasion is full of interest, not only as an anniversary, but also as an illustration of the slow growth of that love of nature and gardening which has now attained such imposing proportions among us.

The beginning of the garden idea in connection with a college dates back considerably more than a century. Over two hundred and thirty years ago, indeed, Leonard Hoar, then president of Harvard, wrote as follows to the philosopher Robert Boyle, respecting a botanic garden: "A large, well-sheltered garden and orchard for students addicted to planting . . . are in our design for the students to spend their times of recreation in them; for reading or notions only are but husky provender."

The Botanic Garden did not then become a reality, however. It was almost another century, in fact, before anything more was done about the matter. In 1784 the General Court of Massachusetts was asked by the Corporation of Harvard College to aid in founding such a garden. But the State was impoverished after the long and exhausting war of independence, and though the King of France offered, through his consul-general at New York, "to furnish such a garden with every species of seed and plants which may be requested from his royal garden at his own expense," his offer was respectfully declined—and for twenty years more the project slumbered.

On the first day of March, 1805, however, we find the books of the Harvard Corporation recording "a plan for a professorship of Botany and Entomology in the University," which was communicated and read to a number of subscribers to a fund for that purpose. At subsequent meetings the proposed statutes and regulations were discussed, and on March 28 these were adopted. After the induction of Prof. Peck into the first chair of Natural History ever established in an American college, and the inaugural oration in English which accompanied the ceremony, "they sat down to a decent dinner in the Hall," declares the minutes.

Dr. Peck addressed himself heartily to the task of laying out the Garden. Wishing to have an acquaintance with the most noted European parks in order to serve his charge to the best advantage, he immediately went abroad for a tour of travel and observation. By 1808, however, he was back in Cambridge building a greenhouse (on the site which had been purchased through the subscription and by means of a grant from the State of wild lands in Maine), and arranging for his initial lectures in natural history. There were at first small classes and scanty returns from the Garden. The story of those pioneer years is indeed one of constant struggle. The original subscribers seem to have assumed no responsibility to sustain the noble enterprise they had founded, and no means were at hand for the adequate support of the work. The manner of supplying the Garden with new specimens was admirably simple and neighborly; Cambridge gentlemen having greenhouses presented the Garden with new plants "as they happened to acquire them." Living exotic plants could then be purchased by applying to the gardener, and the meager receipts were further increased by a charge of twenty-five cents levied upon each visitor. "Strangers of distinction, clergymen, and those connected with Harvard" seem to have been the only people admitted gratis in the early days.

After Prof. Peck's death, in 1822, funds were at such low ebb that his chair was allowed to remain vacant. But this interregnum period is by no means barren of interest, inasmuch as Thomas Nuttall, the distinguished botanist, who had been several years in the country, was appointed curator of the Garden, and gave such instruction in natural history as was at that time demanded. Nuttall was a good deal of a "character." In England he had been a compositor in a printing office; but a passion for travel having seized him, he abandoned this peaceful occupation and came to America to explore the sources of the Missouri and the Arkansas. Captured in Philadelphia by Bos-

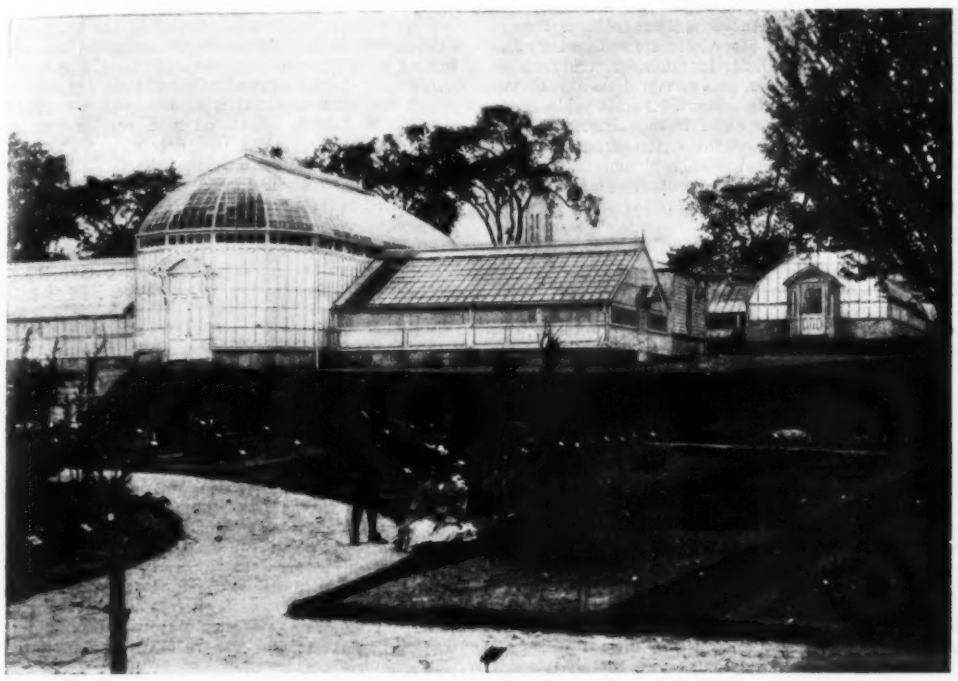
A SMALL SECTION OF THE GARDEN.

PROF. ASA GRAY'S HOUSE AND HERBARIUM.

HARVARD'S BOTANIC GARDEN.

* From American Homes and Gardens, Published by Munn & Co.

ton friends. Nuttall was brought on and established in Cambridge, where he remained for several years, troubling himself little with students, but doing a valuable service to natural history, nevertheless, through his "Manual of the Ornithology of the United States," a work remarkable for the close knowledge it



THE PALM HOUSES.

reflects of the habits, manners and affinities of our birds. The preface to this book is generally admitted to be one of the most admirable essays in the literature of ornithology—a classic for which Boston may well enough claim the credit, inasmuch as the book was incited by Mr. James Brown, who was one of the founders of the Boston publishing firm of Little & Brown. Mr. Brown was himself a lover of ornithology and a good friend of Nuttall. Evidently he was one of the few whom the naturalist permitted to share in his hermit-like life. So desirous was Nuttall indeed of avoiding his fellow creatures, that he never used the stairs of his house adjoining the garden, but reached his sleeping apartments by means of a trap-door and stepladder. A panel hung on hinges in the door which connected with the kitchen served for the passage back and forth of a tray upon which his daily food was handed through.

After ten quiet years in Cambridge, Nuttall was seized by another attack of his old Wanderlust, and departed suddenly for the Sandwich Islands, returning by way of the Cape of Good Hope in the vessel which had for one of its crew the author of "Two Years Before the Mast." After a sojourn in Philadelphia, the eccentric naturalist went back to live and die in England. He had been here long enough, however, to do a great work for ornithology and to supply Cooper with the Dr. Battius of his prairie life novel. Nuttall is further interesting as the precursor of Ernest Thompson Seton, who hunts without powder. It is related of him by Ernest Ingersoll, the naturalist, that once, when guns were called into sudden requisition during a journey across the Rocky Mountains, Nuttall's fowling-piece was found stuffed to the muzzle with bulbs of new species.

Not until 1842, when Dr. Joshua Fisher, of Beverly, Mass., a Harvard man of the class of 1766, endowed a professorship of natural history, to which Dr. Asa Gray was promptly called, did an era of prosperity dawn for the Botanic Garden. Dr. Gray was then only thirty-two years old, but already he had attained marked distinction in his chosen branch of knowledge. From the first year of his coming to the college a glowing interest in botany developed among the students. Quarters had to be enlarged, courses extended, and the corps of workers for the garden increased. Unfortunately, though, there was no corresponding augmentation of the endowment. Only Dr. Gray could have kept the enterprise going with such inadequate funds as were at his disposal. By the expenditure of untiring energy, however, this very able curator enriched the display by large numbers of native and foreign plants, and soon caused the garden to become the recipient of the newer treasures coming from the West and Southwest. Dr. Gray was wont to place in nooks not easily accessible to the public the rarer plants, which have since become the common property of horticulture, and in this way he introduced some of the choicest novelties.

No worthy branch of Harvard University seems to have suffered more, first and last, for lack of support, than the botanic garden. About 1860 it became a serious question, indeed, whether all operations there should not cease. At this critical period, however, a subscription of $1,500 a year for three years was raised through the exertions of Dr. George Hayward, to give temporary relief, and in 1864 Nathaniel Thayer gave a building for the invaluable Herbarium, comprising over two hundred thousand plants, and the library of twenty-two hundred botanical works (including an autographed copy of Goethe's "Metamorphosis of Plants"), presented to the university by Dr. Gray. In 1871 H. H. Hunnewell added a lecture room. Money for running expenses was still lacking, however; and from 1872 Dr. Gray had no salary but his house rent, and personally bore the expense of a curator for the Herbarium which he had presented to the college. During these latter years, though, the professor had no classes, but devoted his entire time to the completion, in the sunny study which adjoins the Herbarium, of his long-delayed "Flora."

The classes had meanwhile been placed in the hands of Prof. George L. Goodale, who is still at the head of this department at the college, and who is also now the curator of the garden. In the twelve years between Dr. Gray's relinquishment of the active duties of the curatorship and Dr. Goodale's assumption of them, Prof. Charles Sprague Sargent was in charge of things, at the corner of Linnaean and Raymond streets, Cambridge, and it is to his skill and to the increased funds resulting from a vigorously conducted subscription canvass that the Garden owes much of its present attractiveness. The distribution of species was changed at this period, and many improvements, which poverty had hitherto forbidden, were successfully introduced.

For inspection the garden may be conveniently divided into the upper level and the area below the terrace, where the natural order of flowering plants and the genera of ferns and their allies are arranged in formal beds, so disposed as to exhibit many of the affinities of the families. Here, too, are special beds devoted to groups of plants of particular interest—such as those mentioned by seventh century writers, and those celebrated by Virgil and Shakespeare.

The Shakespeare garden is the most interesting spot in the estate's whole seven acres, not only on its own account, but also for the suggestion it offers to private garden makers. At this time of the year the marigold is particularly conspicuous among its flowers of long and distinguished lineage. Perdita says:

> "The marigold that goes to bed with the sun
> And with him rises weeping; these are the flowers
> Of middle summer."

Strolling farther along the grass-bordered walk, away from the greenhouses, that alluring trio, mint, balm, and savory, are found, all of which are attractive plants, though not in bloom in the late summer. The gardener here will tell you that savory is not named from its qualities of taste or savor, but is a corruption of the old Italian name—savoreggia. The marjoram—mentioned in the lines—

> "Here's flowers for you,
> Hot lavender, mint, savory, marjoram"—

is not, however, to be found in the Shakespeare bed, but just across the way in the Virgil garden. Here also is the rosemary, so well remembered by Ophelia's mad lines, "There's rosemary that's for remembrance;

ONE END OF THE VIRGIL GARDEN.

THE GREAT AUCLERS AND THE BEECH HEDGE.

HARVARD'S BOTANIC GARDEN.

pray, love, remember," and by its homely property, the keeping of moths out of old-time clothes chests.

The violet, the rose, the columbine, the primrose, the poppy, the pinks, and the pansies, all so well known, most of which are so often mentioned by Shakespeare, and all of which have for us deep and tender associations, are appropriately included in the parterres of

this Shakespeare garden. The rose is mentioned by Shakespeare more often than any other plant. He speaks of at least eight varieties—particularly, of course, of the white and red, made famous by the rival wars of York and Lancaster, in the so-called historical plays, and the damask, which, originally taken by the Crusaders from Damascus, was brought to England by Dr. Linaker, physician to King Henry VII. The English daisy, too, is here, though now past its prime, being a flower of spring, the same as the violet, spoken of by Shakespeare in the "Spring Song" from "Love's Labor Lost":

"When Daisies pied and Violets blue,
And Lady-smocks all silver white,
And Cuckoo Buds of yellow hue
Do paint the meadows with delight."

In this garden one may find not only plants pretty in blossom, but the more modest species which are useful as food or from which medicine was brewed for the ailments of the sixteenth century: barley, various species of beans, the bramble with its seed-laden berries—to which Falstaff refers in his rant, "Give you a reason on compulsion—if reasons were as plentiful as blackberries, I would give no man a reason on compulsion"; flax, with seeds that were made into healing poultices for mediæval as well as modern sore backs; oats, and the climbing vetches, which are thought by some scholars to be the tares mentioned in the parable of the sower. Shakespeare speaks of a number of these grains in "The Tempest," where Iris addresses Ceres:

"Most bounteous lady, thy rich leas
Of wheat, rye, barley, vetches, oats and peas."

There is also the tart rhubarb, which the great poet mentions as a purgative drug, but which, in Elizabethan times, probably had no culinary use, together with its botanical cousin, the dock, spoken of by Bergundy in "Henry V.," and the hardy leek and tearful onion. The qualities of these last as food were evidently appreciated by Shakespeare, for Bottom is made to say to his fellows: "And most dear actors eat no onions or garlic, for we are to utter sweet breaths."

In the shade of the trees which line the western edge of the Shakespeare garden grows the "cold lettuce" and the hyssop—both referred to by Iago in his famous metaphor of the human body and the garden—the former plant noted for its narcotic qualities, the latter for its part in the cruelties of the Crucifixion. Near by grows our American potato. It is interesting to note that almost the earliest mention of potatoes, after their introduction from Virginia into Ireland in 1584 by Sir Walter Raleigh, is made by Falstaff in "The Merry Wives of Windsor," where he says: "Let the sky rain potatoes; let it thunder to the tune of green sleeves." In this same bed is the familiar radish, considered by the Elizabethans as a preventive of snake bites; the plantain, to which great medicinal properties were attributed; the old spicy mustard, the poisonous aconitum, which Shakespeare compares in deadly qualities to the "rash gunpowder," and the parsley, which recalls the speech of Biondello in "The Taming of the Shrew." "I knew a wench," says he, "married in an afternoon as she went to the garden for parsley to stuff a rabbit"—showing that this universal herb was used as a garnish as far back as the time of the Armada and the Globe Theater.

The ivy, which ordinarily "enrings the barky fingers of the elm," and pervades all romantic literature, seems to have been only a vicious parasite to Shakespeare's mind. In several passages he refers to it in the same spirit as in the "Comedy of Errors," where it is called "usurping," and again in "The Tempest," as "the Ivy, which had hid my princely trunk, and sucked the verdure out on't."

What with this interesting classical department (started five years ago by Prof. Goodale), the Virgil garden, the seventeenth century plants of Parkinson and the native species, it ought to be very easy to develop a knowledge of horticulture or to study botany in Cambridge. After a woodland search one has only to bring the treasures here and find their names, not by picking the pretty blossoms to pieces and laboriously searching among the dry technicalities of a dusty volume to find their genus and species, but by comparison with the blossom's living brethren. People have begun to find this out, too, and now they come as early as February to see the roses, cyclamens and cinerarias, then in bloom under glass.

The garden is never quite bare. From earliest spring to late autumn something is blossoming. In March there are snowdrops and crocuses in sheltered places near the greenhouses; in April the hardy perennials begin to appear; and from then on, of course, there is a wealth of color and fragrance here to be enjoyed. Beside each growth is thrust into the ground a little tablet containing the scientific and common names of the plant and its habitat. The visitor may even pluck up this record for more convenient reading, if only he takes care to put it back into its proper place.

Among the most constant visitors to the botanic garden are children, who have become familiar with many of the common flowers through their kindergarten instruction. These little folk make a very pretty picture in their bright cotton dresses, as they march two and two along the green-bordered paths. Yet when all is said it is the people who most enjoy the treasures of this unique spot. Though Harry and Harriet may not be able to quote verses to illustrate the Shakespeare specimens, they appreciate thoroughly the privilege of being permitted to wander at will over the grounds and through the greenhouses. Often four hundred visitors come to the Garden of a Sunday afternoon. It is the one Harvard department which is "popular."

The greenhouses of the botanic garden make very little pretense of architectural glory, but regulations for preserving the proper temperature are on the most approved plan, and the arrangement of the specimens is capital. The gaudy ornaments of the florist's shop, azaleas, camellias, carnation pinks and the like, may perhaps be missed, but there are hundreds of things here not to be found in other greenhouses and of distinct interest. The cacti, for instance, are truly extraordinary. Their blossoms, you note, are out of all proportion to the size of the plant. A miserable little thing has a flower some eight inches long, while an American cactus, which would weigh three hundred pounds, shows only a shy half-inch bloom.

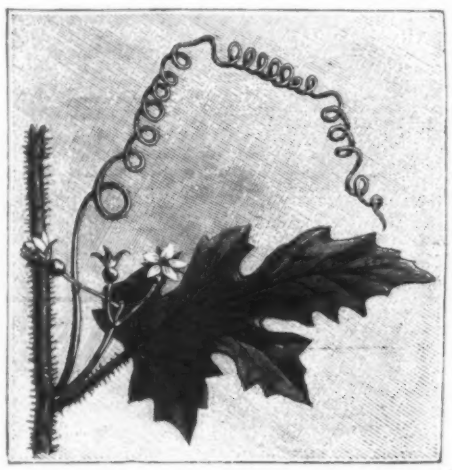
The division given over to economic plants excites great popular interest at all times.

THE DIRECTION IN WHICH VOLUBLE PLANTS TWINE.

CERTAIN plants that are too weak to raise their stems above their neighbors of themselves in order to obtain the light necessary for their existence, effect such a result by twining around objects which stand in the vicinity. Sometimes it is by their stem which winds in a spiral, and sometimes it is by corkscrew-like tendrils that they cling to the object.

Although numerous researches have been made on twining plants, none of them has given a satisfactory explanation of the phenomenon, which remains connected with vital laws inaccessible to our means of investigation. The intervention of electricity, applied either to the plants themselves or to their support, has no influence. Nor have light, heat, and humidity any direct action upon the twining itself, but can only hasten or retard it in the same proportion in which they produce such effects upon non-twining stems. Moreover, light which usually attracts the young organs of plants, sprouts and leaves, toward it, seems here to exert a repelling action, and solidifies the side of the stem upon which it falls.

It has been remarked that in the kidney bean the



CHANGE OF DIRECTION OF TWINING IN THE SAME TENDRIL BRYONIA.

twining is accelerated in measure as the plant grows. While the stem at the outset describes scarcely one revolution a day, later on it makes eight in the same period. The stem in the act of twining approaches its support more or less according to the species and according to the hour of the day.

The spirals are wider according as the support is larger or smaller; but if the latter exceeds a certain size, the stem will not twine around it. Twining plants which are not situated in proximity to a support, trail and do not thrive well.

In every plant the stem in process of growth describes by its point movements of *circumnutation*, that is to say, it directs its apex successively toward all the points of the horizon in describing an elliptical spiral. In the twining species these motions are very marked, and their stem describes in the air ellipses that are often very elongated. It seems to seek a proper support tentatively, and in all cases these movements facilitate its twining.

The direction of the twining is almost absolutely constant not only in the same species, but in the same genus and often in the same family. Now it takes place in a direction contrary to that of the hands of a watch, or *sinistrorsum*, and now in the same direction as the hands, or *dextrorsum*. In order to appreciate this it is necessary to imagine ourself situated in the middle of the spirals, in the place of the support. The naturalist Palm, who wrote a general work on twining plants quite a long time ago, reckoned twenty-five genera in which the twining was to the left (*sinistrorsum*), and ten in which it was to the right (*dextrorsum*). The first belonged especially to the Leguminosæ, the Asciepiadaceæ, the Passifloraceæ, and the Cucurbitaceæ; and the second to the Capripoliceæ, the Urticaceæ, Smilacinaceæ, and the Filicaceæ.

More recently Wollaston has seen a relation between the course of the sun during the day and the spiral direction of twining plants, and has concluded that such direction must be contrary in the two hemispheres. This opinion, which is entirely hypothetical, was advanced again a few months ago apropos of the labors of the Messrs. Brunhes on atmospheric whirlwinds and the whirlpools of the watercourses of central Europe; and a relation was imagined between the cause that produces the direction of such vortices and that which determines the twining of plants.

This theory, however, is quite unlikely. We know, in fact, twining species that are dextrorsum, and others that are sinistrorsum on each side of the equator, and, moreover, the various species of the same genus which grow in both hemispheres maintain the direction of their twining constant. Finally, the tendrils of climbing plants of which the spirals are certainly due to the same mechanism as that which causes the twining of voluble stems, offer in certain species a change and direction toward their center. This may be easily seen in the grapevine, the Bryonia and the Cobœa.—Translated from La Nature for SCIENTIFIC AMERICAN SUPPLEMENT.

HYBRIDIZATION OF PLANTS.

IT is a singular fact that it is only during the past century that hybridization, or cross-breeding of plants, has been practised.

Lord Bacon, more than 300 years ago, seems to have foreshadowed it, but it was generations before anyone attempted to solve the mystery.

Lord Bacon wrote: "The compounding or mixing of plants is not yet found out, which if it were, it would be one of the notable discoveries, for so you would have great varieties of fruits and flowers yet unknown."

Who was the first to cross a fruit or flowers we have no data to prove, but Mr. Knight, of Chelsea, England, was very much interested in, and practised the art of hybridization. When the secret was found out the practice soon became common, and some enthusiastic amateur horticulturists engaged in it. Since then the art of hybridization has been followed by many, and, as Bacon suggested, greatly improved and unknown varieties of fruits and flowers have been produced in rich abundance.

Perhaps in the amelioration of fruit it has been important, now marvels of the hybridist's skill are crowding upon us, and they seem to accomplish their aims with a certainty that is remarkable—for instance, in the case of the stoneless plum, which Mr. Burbank, of California, after twenty-five years of study and experiment has been able to give to the world, and now the coreless apple of Mr. Spencer. It has taken these gentlemen years to accomplish the object they had in view, but to raise a new grain, fruit, or flower or vegetable of greatly superior qualities is worth a lifetime of patient and persevering effort, because it contributes to the welfare of the human race, and the comfort of the lower animals.

Cross-breeding is the most important, useful, and fascinating branch of horticulture and sometimes very remunerative.

In order to obtain a new variety it is only necessary to exercise some judgment, and select two parents of certain qualities which are of the same, or of very closely allied species, and cross them for a new intermediate variety, which will blend the good points of both, and thereby effect an improvement; thus an early, but insipid pear, if crossed with one of fine flavor, but lacking the desirable qualities as to habit of growth or productiveness, will be likely to bring a variety which in some essential points will surpass either of its parents.

The "Goe's Golden Drop" plum was raised by crossing the Green Gage with the Magnum Bonum plum; the Elton cherry was raised by crossing the Byarrean with the White-heart, and the combinations have produced the two invaluable fruits mentioned.

The power to cross-breed is limited by a wise provision of nature to prevent the generation of monstrosities. A cross-bred plant is a sub-variety raised between two varieties of the same species. Some nearly allied species are capable of fertilizing each other and these are pure hybrids or mules, and, like animals so bred, are incapable of producing perfect seed. No one has ever succeeded in causing the pear to fertilize the apple, or the gooseberry the currant. Before people were so well informed on these subjects as they now are it was believed that wonders could be brought about by fertilizing an orange with a pomegranite or a red rose with a black current, but these fancies are no longer accepted as being possible.

Now, as to the *modus operandi* of the artificial crossing of plants. Take the blossom of a cherry, for an example, which is directly connected with the embryo seed; the numerous surrounding threads are the stamens at the summit of which are little sacks which secrete the powder called pollen. The pistil has its base in the embryo fruit and at its summit is the stigma; the pistil is also called the style, and is the stalk or tube between the ovary and the stigma; on this stigma is a sticky substance, when it has arrived at maturity, to which the pollen adheres and thus the seed is fertilized. Now, if we fertilize the pistil of one flower with the pollen of another we shall obtain a variety with the characteristics of both parents.

The process of obtaining cross breeds is easily performed. When the tree blooms, which we intend to make the mother of the improved race, we select one of the blossoms not fully expanded; with a pair of sharp scissors we cut off the anthers or pollen sacks. As soon as the blossom is fully expanded, collect with a camel-hair brush the pollen from a fully blown flower taken from the tree we intend to be the male parent. Apply the pollen, and leave it upon the point of the stigma. It is safe to cover the flower thus operated upon with a bag made of thin gauze to prevent

insects geting beforehand with us in applying the pollen. To sum up, the two essential points are: First, to be very careful to remove the anthers before they are sufficiently mature to have fertilized the pistil; second, to apply the pollen when it is in perfection, that is, dry and powdery, and when the stigma is moist and in condition to assimilate it. Seedless fruit is produced by removing the pistil before it has been pollenated, so that the fruit will form and contain but few if any seeds, and by selecting those which have the least seed and repeating the process in course of years seedless varieties will be the result.

STAR-STREAMING.

IT is often very difficult for the layman to grasp how astronomers can fix the positions of celestial bodies with that wonderful accuracy of which every eclipse and every occultation gives fresh evidence. The earth turns about on its axis, but that axis vacillates, though very slightly indeed, yet perceptibly. By the time the earth has completed its yearly orbit around the sun, the sun has swept millions of miles in its course through space apparently toward α Lyræ. Various methods allow us to trace the character of this motion. Star-groups which we are approaching seem to open out; those which we leave behind seem to close up. Photography and spectroscopy afford further means for ascertaining the character of our motion, and the various determinations of "the apex of the sun's way," towards which we are drifting, agree within a few degrees. We know of hundreds of pairs of stars which revolve round their common center of gravity. The movement of our moon is still more complex than that of the earth; and if every member of our planetary system describes a complex path, we may reasonably expect that complex orbits will prove the general rule, and the determination of the position in space of any particular star would appear an almost hopeless task. Yet astronomers attack it with success. If there is motion everywhere, and if the whole universe is conforming to the same laws, then we might feel inclined to anticipate that some particular directions of motion will predominate for the many star systems. They need not all circulate around one central star, so as to form one universal sun and planet system. But the universe may represent other apparently complex, and yet finally simple, combinations of systems.

It is only within quite recent years that any attempts have been made—or could be made—to approach these problems, in whose consideration centuries may count for little. When the constant of the precession of the equinoxes is to be derived, or the motion of the sun through space is being investigated, it is usually assumed that the apparent proper motion of the various stars follows no general law. There seems to be no preference for any particular direction; but, in 1895, Kobold announced that the assumption of a random distribution of the direction of the star motions was incompatible with certain facts.

During recent years Prof. J. C. Kapteyn, of Groeningen, in the Netherlands, has been studying this most difficult problem. Prof. Kapteyn is a professor of astronomy who does not possess an observatory of his own. In a research of this kind the personal observations of even the most successful worker would, however, count for little. An authority of the first rank, Prof. Kapteyn analyzes the material collected by his colleagues; and he has in this particular field, of what may perhaps briefly be designated as "star classification," obtained undisputed pre-eminence.

Now, Prof. Kapteyn has arrived at the conclusion that we have in the universe to deal with two star-streams moving in opposite directions. He offers no suggestion as to the explanation of these two streams. When communicating the results of his calculations to the recent British Association meeting at Cape Town, he refrained from all speculations. He would have preferred to keep the remarkable conclusions which have forced themselves upon him to himself, until he could apply further crucial tests. But the task is vast, the publication of the ledgers of the American astronomers on radial velocities, to which he particularly looks forward, may be delayed, and it was in the hope of eliciting further spectroscopic data that he made his announcement at Cape Town. The communication, it is hardly necessary to say, excited a most unusual interest. If Prof. Kapteyn's main conclusions are accepted, our views on star motion must be revised. We shall have a long while to wait for something of the nature of a confirmation or refutation; meanwhile the hypothesis will be widely discussed, and we will therefore attempt to place an outline of the arguments before our readers.

Let us assume, for simplicity's sake, all the stars of a certain group concentrated near the center of a sphere. Each star has is own peculiar, or so-called "proper," motion. If all these motions occur in random directions, the stars will appear to move all in radial lines, and a diagram of their motions would be radially symmetrical. In addition to the proper motions of the stars, we have, however, to consider the motion of the solar system as such, with which the observer travels—the parallactic motion. This parallactic motion has a definite direction, common for all the stars, away from the apex—the point at which the prolongation of the sun's path would meet the sphere—toward the antapex. What the astronomers observe are the resultants of the proper motion and the parallactic motion. If we take the line apex—antapex as the X axis, then the radii, representing the proper motions of the stars, will, owing to the parallactic motion, appear to become longer in the direction toward the antapex, and shorter in the opposite apex direction—that is, longer on the right half of the diagram, and shorter on the left. The radial symmetry of the diagram thus passes into a bilateral symmetry with regard to the X axis.

If we now determine the lines of symmetry for several points of the sky, and prolong these lines, all these lines should intersect in two points—the apex and the antapex. In this way the position of the apex and the antapex could be fixed. As the observations on which these computations are based are exceedingly delicate, and as so far only a comparatively small number of points of the sky have been investigated, we can hardly expect real lines of symmetry, and must be satisfied with an approximation. The analysis may be carried on in various ways. Prof. Kapteyn defines the line of symmetry as the line (abscissa X) for which the sum of all the ordinates (Y) becomes zero. These lines of symmetry, finally, will not pass through a single point, but will intersect within a certain area, the center of gravity of which Prof. Kapteyn regards as his apex. Great circles passed through this apex will necessarily deviate a little from the lines of best symmetry; but if our presumption be correct—viz., if the stars move radially in random directions—this deviation should be small.

The way in which Prof. Kapteyn proceeded in his elaborate analysis can merely be indicated. He divided two-thirds of the whole sky into twenty-eight areas, and determined in each of these twenty-eight cases the distribution of the directions of the proper motions corresponding to the center of gravity of the respective area. His explanatory diagrams exhibited at Cape Town dealt with ten of these diagrams. The apex was in each case determined by various methods, more or less akin to one another. Prof. Kapteyn finally obtains certain polygons, built up of more or less dark portions; if there were any random direction, the white and the black portions of each polygon should be equal in area. But this is clearly not so, and there are regular divergencies, systematic with regard to the Milky Way. The figures belonging to stars situated near the poles of the Milky Way are of the same character. Near the south pole the areas of the black portions come out greater than those of the white portions, and the opposite holds for the north pole of the Milky Way. There can be no doubt about the reality of the phenomenon, and the divergencies are far too great to be explained by the uncertainty of the precession, or by the systematic correction which Bradley's observations require. The determination of the apex is more doubtful, and Prof. Kapteyn therefore tested this determination by various methods. But the character of the divergencies remained unaltered; and this fact seems to force upon us the view that the different stars do not move at random in any direction, but that there are certain favored directions.

Most of the diagrams suggest two favored directions; in a few cases only one favored direction can be traced. Entering these two sets of favored directions on a globe, Prof. Kapteyn found that the direction of the various sets all converged approximately to two points—that is, the one group of favored directions of the separate sets converged to one point, and those of the other direction to another point. The two points lie 140 deg. apart, the one about 7 deg. north of α Orionis, the other a few degrees south of η Sagittarii.

What does this mean? When the motions of a group of stars converge to one point, we may assume either of two things. Either the motions are really parallel to one another, and the convergence is a matter of perspective; or the motions are only apparent, and really due to the observer's own motion in the opposite direction. Unless we find a fixed point of reference, we cannot decide which of the two conclusions is to be accepted. In this case, however, the latter assumption fails for one of the two groups at least, because the motion of the observer in one direction could not convey the impression of a movement of the stars in two directions.

We are thus led to assume that there are two star-streams in opposite directions, parallel to the lines joining the two points mentioned. Although the position of the solar apex cannot yet be regarded as rigorously determined, this apex does not appear to coincide with either of Prof. Kapteyn's points. The above-named two directions are only apparent, however, relative to the solar system. Prof. Kapteyn has been able to determine the real points toward which the star-streams appear to be directed. He calls these points the vertices. The conditions of his problems, he stated, are such that the vertices of stellar motion must be diametrically opposite to one another; there was no time to explain why this must be so. The one of the vertices lies near to ε Orionis, the other diametrically opposite, in a portion of the sky not distinguished by bright stars. Both lie in the middle line of the Milky Way, and have the galactic latitude of 2 deg. (on Gould's system of co-ordinates).

The statement that there are two main streams of stars should not be understood to imply that the stars are all traveling toward either vertex. Prof. Kapteyn claims only a decided preference; and, further, that all the stars seem to belong to either one or the other of the two groups. The stars of the Orion group, which to all appearance are nearly at rest in space, form an exception.

The evidence on which these conclusions are based concerns more especially seventy-eight stars, and, further, forty-six spectroscopic binaries. The data available as to the proper motions of stars are scanty, and had, moreover, to be sifted for this particular analysis. Some stars have been selected for study on account of the excessive character of their proper motion, or of its velocity. These have been excluded as exceptional cases. Then Campbell has discovered that the bright stars have, on the whole, smaller motions than the average fainter stars. This is a very important discovery, both on general grounds and in connection with our subject. If we rely chiefly on the bright stars, we get a very small proper motion for the solar system. Prof. Kapteyn believes that the stars nearest to the solar system partly participate in the motion of the solar system, and his inquiry into this side-issue has strengthened his case. He has considered stars down to magnitude 9. The spectroscopic examination of the bright stars should, on account of their slower motions, mark the phenomena under discussion less strongly than that of the fainter stars. Prof. Kapteyn finds the expected gradation.

Other facts observed support his hypothesis. But he is, of course, himself most anxious to have it further investigated, and he suggests the examination of a few hundreds of stars below 3.5. If further researches supported him, he remarked in concluding his communication, we might safely go on; if not, such researches would help us to find the real clue. There was nothing speculative in his memoir. The anomalies that his most laborious investigations—which he has been carrying on, we believe, merely with the aid of computers—have brought to light, are too marked to be put down to instrumental errors. They must be of cosmical character; and whether or not the peculiar two star-streams of opposite directions be acquiesced in, the problem touches the very foundations of cosmical astronomy, if that term be permitted.—Engineering.

COST OF RUNNING A MOTOR DELIVERY TRICYCLE.

ALTHOUGH considerable prominence has been given one time or another, to the costs of operating motor bicycles under the various exigencies of continuous and intermittent service, there has never been given until this time, any accounting of the cost of operating the three-wheel type of machine for business uses, nor even any authentic data as to the performance of such machines in regular service On that account the following figures giving the record of 25 days' work done by Peter Hanson, who rides a Manson motorcycle with a delivery box attachment in the service of A. Stevens & Co., of Chicago, Ill., silk merchants, are of uncommon interest.

During the twenty-five days, seventy-six trips were made in all, on an average of three trips per day, while the average time consumed in each trip, including the time of delivery, was 1 hour and 35 minutes. The total goods delivered amounted to 2,273 packages, or an average of 91 packages per day, which were carried an average distance of 4.8 miles, or 9 2-3 miles per trip, making a total mileage of 726. The cost figured out at something like ten cents a day for gasoline, which sufficed to carry the machine its daily average of 29 miles. The record in detail follows:

Date.	Number of Trips.	Time Delivering.	Number of Packages.	Number of Miles.
Dec. 6	3	4h 15m	132	29
" 7	3	4h 45m	78	21
" 8	3	4h 30m	87	27
" 9	4	5h 30m	116	31
" 12	4	6h 30m	157	38
" 13	3	5h	96	27
" 14	3	5h	91	28
" 15	3	4h 45m	113	28
" 16	5	5h 45m	105	35
" 18	2	3h	69	21
" 19	4	4h 30m	82	35
" 20	3	5h 30m	121	41
" 21	1	1h 30m	15	18
" 22	3	4h	81	26
" 23	4	3h 30m	58	30
" 26	2	2h	25	17
" 27	3	4h	54	23
" 28	2	3h	47	18
" 29	2	4h	50	29
" 30	4	6h 30m	99	68
Jan. 2	1	3h	56	15
" 3	4	7h 30m	123	31
" 4	3	5h 30m	131	30
" 5	3	8h	158	29
" 6	4	7h 15m	129	31
Total 25 ds.	76	118h 45m	2273	726

Even though the figures are not extended to give an accounting of the cost of other supplies, and the approximate rate of maintenance, the average of less than a cent a mile for fuel demonstrates the utility of the machine from an economical standpoint, and reveals something of its relative standing as a competitor of the light horse-drawn delivery wagon.—Bicycle World.

Very early in the study of polluted waters attempts were made to devise methods for detecting certain definite organic compounds which were known to be formed by the decomposition of the nitrogenous products contained in sewage, but without success, and there is very little hope that much knowledge can be gained as to the nature of the organic matter through this line of investigation. The decomposition of the nitrogenous products contained in sewage takes place so rapidly that the isolation of any particular compound like crystin, or any group of compounds, like the amido group, can be looked for only when the pollution is very recent and in very large amounts.

THE PRESSURE OF EXPLOSIVES. EXPERIMENTS ON SOLID AND GASEOUS EXPLOSIVES.*

By J. E. PETAVEL.

INTRODUCTION.

THE scientific treatment of this question may be said to date from the researches of Count Rumford who,

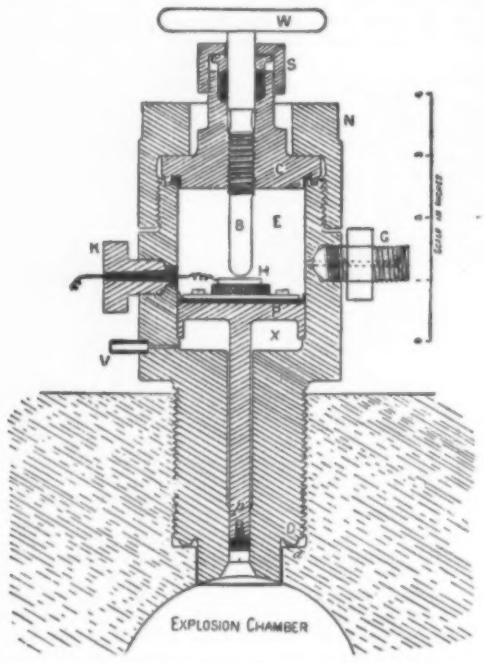


FIG. 1.—EXPLOSION GAGE. (MAXIMUM PRESSURE INDICATOR.)

The gage consists of a double-headed piston, *P*, *p*. The smaller head, *p*, is exposed to the pressure of the explosion, which is counterbalanced by a fixed gaseous pressure acting on the larger head, *P*. The ratio of the two areas (and therefore of the two pressures when in balance) is fifty to one in the case of the gage illustrated in this drawing. The lift of the piston is limited to about one hundredth of an inch, the distance of the stop, *B*, being adjusted by means of a fine screw. The piston on lifting closes an electric circuit and works an indicator. *S* is the stuffing box through which the stop, *B*, passes. *C* is the cover of the cylinder in which the piston, *P*, works; it is held down by the nut, *N*. *G* is the gas inlet by means of which the space, *E*, is connected to a source of supply of gas under pressure and to a gage. *K* is the plug through which the electric connection to the insulated contact-piece *H* is made. To prevent back pressure, which might arise through leakage past either of the leathers, the space, *X*, is connected with the atmosphere by means of the vent, *V*.

at the end of the eighteenth century, devised the first apparatus by which explosive pressures could be estimated with some degree of approximation.

During the past century the natural fascination of the subject, and the importance of the problems involved, attracted many of the ablest scientific minds. Several have made the study of explosions the object of their life work.

In the short space available, an adequate historical epitome is unfortunately impossible. A mere enumeration of the names with which we shall most frequently have to deal must therefore suffice.

Our knowledge of the behavior of solid explosives is due principally to the brilliant work of Noble in this country, and of Berthelot and Vielle abroad. With regard to explosive gaseous mixtures, the exhaustive work of Le Chatelier and Mallard in Paris, of Dixon in Manchester, and Clerk in London, is familiar to all.

At first sight it may appear to be over ambitious on the part of the author to attempt to add to the edifice built up by such able investigators. Close consideration will, however, show that there is a gap in the structure ready to be filled by the small stone which he has quarried out.

In the case of solid explosives, thanks to Noble's crusher gage, the actual maximum pressure attained can be accurately measured. The mechanism of the explosion itself and the rate at which the pressure rises from the moment of ignition need, however, further investigation.

For gaseous explosives the same criticism holds true, more especially for mixtures which are highly compressed before they are fired. The first case has a bearing on all ballistic problems, the second provides some of the data necessary to the designers of the modern gas engine, and thus both are of considerable practical, as well as scientific importance.

PART I.—METHODS AND APPARATUS.

Explosive Pressure Gages.

At the time this research was started, some six years ago, there was no instrument by means of which the variation of pressure during the course of such explosions could be satisfactorily recorded. Numerous attempts have been made, but without success, to reduce the moment of inertia of the existing types of recording manometers sufficiently to make them of service for this work. The natural period of oscillation, however, invariably proved to be too slow. In consequence, the curves traced out did not record the rise of pressure in the inclosure, but merely the vibrations set up in the mechanism of the gage by the sudden shock to which it was subjected. To design a satisfactory instrument it was, therefore, necessary to start *ab initio*. Before, however, the work could be carried out, some further knowledge of the conditions prevailing during the explosion was necessary, and this more especially in the case of highly compressed gaseous mixtures, the behavior of which was at the time practically unknown.

Maximum Pressure Gage.

For this work a gage was employed, the construction of which will easily be understood from the drawing given in Fig. 1. In principle the apparatus is the same as that used by Bunsen, and consists of a piston closing an aperture in the explosion chamber, the piston lifting if the pressure of the explosion rises above the load for which it is set.

To reduce the inertia to a minimum, the weights, used in Bunsen's apparatus, are replaced by a gaseous pressure. The moving part consists of a double-headed piston (*P*, *p*), the smaller end of which (*p*) is exposed to the force of the explosion, while the larger end (*P*) closes a cylinder filled with gas at a known pressure. The piston, on lifting, closes an electric circuit and works an indicator. To insure rapid action, the travel of the piston is limited to about a hundredth of an inch.

Two such instruments were constructed. The first,

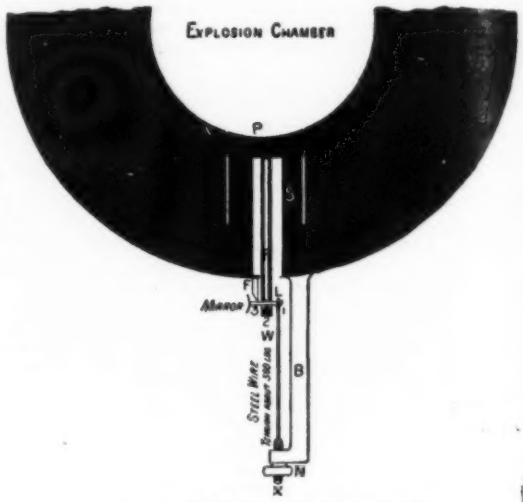


FIG. 2.—DIAGRAM OF RECORDING MANOMETER.

for pressures up to 100 atmospheres, had a ratio of 4 to 1; in the second (shown in Fig. 1), intended for use up to 1,000 atmospheres, the ratio of the areas of the two sides of the piston was 50 to 1. Fairly satisfactory measurements of the maximum pressure were obtained by means of this apparatus.

With this instrument the work is very tedious, and no information is obtained as to the rate of combustion of the explosive. The experience gained during the course of the above preliminary investigation was, however, of the greatest use in the design of the final apparatus.

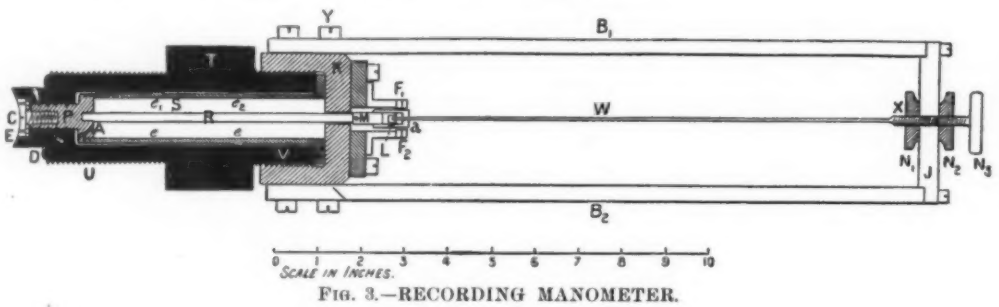


FIG. 3.—RECORDING MANOMETER.

Recording Manometer.

The requirements for a reliable recording gage are somewhat complex. In the case of gases, the explosive pressures to be dealt with range from 100 to 800 atmospheres; in the case of solid explosives it was desirable to extend the research to pressures of 2,000 atmospheres, or above. The combustion of several gaseous mixtures is much more rapid than that of the fastest explosives used in ballistics, and the time period of a recorder designed for this work must, therefore, be exceptionally small.

Before passing on to a description of the instrument it may be well to recall in a few words the law which governs the time period of vibrating bodies.

If *A* represent the force required to produce unit deflection of the vibrating system, and *W* the weight of the moving parts, the time period will be

$$= 2\pi\sqrt{\frac{W}{Ag}}$$

We have, therefore, two variables at our disposal, namely, the weight of the moving parts and the controlling force. The former must be made a minimum, the latter a maximum.

In most instruments where a short period is desirable, the strains to which the parts are subjected are very small, and the desired result is obtained by decreasing the size of all moving parts, and using, wherever possible, materials of low density. This method is employed in the case of all oscillographs, telegraph records, phonograph receivers, galvanometers, etc.

In the present case, the instrument having to withstand pressures of 20,000 or 30,000 pounds per square inch, applied with extreme suddeness, strength becomes a condition of vital importance, and steel is the only material which will withstand the strain. We cannot, therefore, use materials of small density, neither can we reduce the dimensions of the moving parts below a certain limit.

It is thus evident that we must have recourse to the second variable factor to secure the short time period which is necessary. As we have seen above, the controlling force brought into play per unit length of motion must be as great as possible. In other words, we must use the stiffest spring we can obtain.

The stiffness of a spring will vary with the material

*Philosophical Transactions of the Royal Society of London.

VIEW OF THE EXPLOSION CHAMBERS.

of which it is made and with its shape, increasing as the shape approaches more nearly to that of a solid bar subjected to longitudinal strain. This bar can be made as short as may be desired and, in theory, the time period of the system is only limited by the density of the material and by its modulus of elasticity.

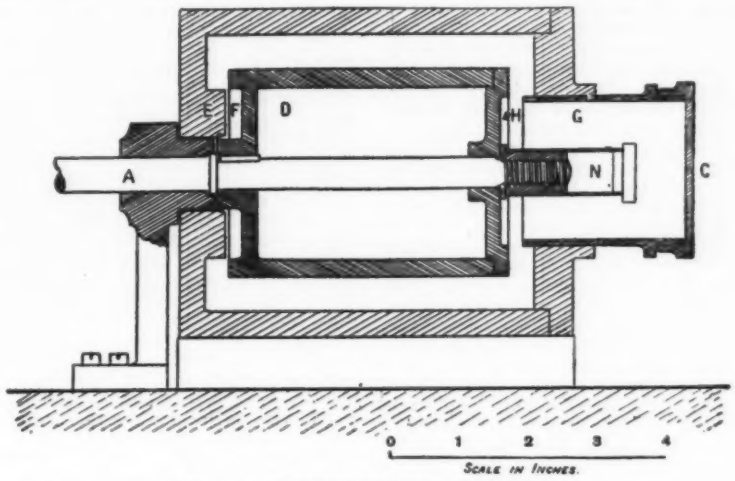


FIG. 4.—CHRONOGRAPH CAMERA.

The drum *D* is shown fixed on the axle *A* of the chronograph. To remove the drum without exposing to the light the film which is wound round it, the camera is first moved a little to the right, causing the ring *E* on the camera to fit into the groove *F* of the drum. The brass tube *G* is next forced into the groove *H*; its cover, *C*, can then be removed and the nut *N* unscrewed. The camera, with the drum firmly held in it, can now be detached from the chronograph (by sliding it to the right) and taken to the dark room, where the film is developed and replaced by a fresh one.

In practice, however, the travel of the moving parts cannot be indefinitely decreased, for the deflections must remain of such dimensions as to be accurately measurable.

The following diagram illustrates the application of the principles we have just established to the construction of a recording instrument (see Fig. 2).

A cylindrical groove is cut half through the walls of the inclosure. The upper part, *P*, of the cylinder thus obtained represents the piston of our indicator, and the lower portion, *S*, the spring. Under the pressure of the explosion the piston, *P*, will be forced outward to an amount corresponding with the elastic compression of the material of which the spring is made. This motion is transmitted to the exterior by the rod, *R*.

The lever *L*, supporting the mirror, rests on the fulcrum, *F*, at 3; it is kept against the knife-edge, 2, of *R* by the tension of the wire, *W*. The wire, *W*, is of considerable length, and is stretched almost to its limit of elasticity. The lever, *L*, can, therefore, follow the small advance of the rod, *R*, without greatly diminishing the tension of the wire, *W*. The mirror focuses a point source of light on to a rapidly-revolving cylinder, thus recording on a magnified scale the motion of the piston, *P*.

It is not impossible that an indicator of this type would work in practice, but the deflection of the mirror, and, therefore, the scale of the records obtained, would be much too small. To increase the deflections, three modifications are necessary—the spring, *S*, must be made longer, the ratio of its cross-sectional area to that of the piston must be decreased, and the knife-edges, 2 and 3, be brought closer together.

In Fig. 3 the design of the actual instrument is given, the lettering being the same as in the previous figure.

By means of the thread, *U*, the gage screws into the explosion chamber, the end, *C*, of the piston being flush with the inside surface. An air-tight joint is formed by the ring, *D*, on the manometer pressing against a flat ledge in the inclosure (see Fig. 5, *a*). The end of the gage from *D* to *E* is a good fit in the walls of the explosion chamber, and the joint is thus protected from the direct effect of the explosion.

The spring *S*, about 5 inches in length, is tubular in shape. To prevent any buckling it is made to closely fit the cylinder, in which it is contained, at two places, e_1 and e_2. The spring is fixed at the outer end *Z*, being held in place by the nut, *K*; at the inner end it is free and supports the piston, *P*. The copper gas check used in the crusher gage is replaced by a leather washer, attached to the piston by the screw, *C*, and to the fixed part of the gage by the ring, *E*. The end of the piston projects by about one-hundredth of an inch, and it can therefore move back, by this amount, without straining the leather.

The mirror (not visible in the figure) is carried by the lever, *L*. This lever is so designed that the knife-edes 1, 2 and 3 (see Fig. 2) are in the same plane, it being at the same time possible to bring the knife-edges 2 and 3 within one-hundredth of an inch of each other, should so great an amplification be found necessary. Up to the present, however, the distance has not been decreased below one-sixteenth of an inch, the scale obtained with this distance being found sufficiently large.

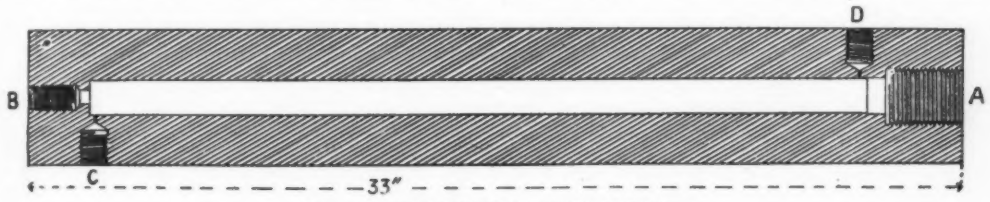


FIG. 6.—CYLINDRICAL INCLOSURE.

The recording gage screws in at *A*, the firing plug at *B*, and two valves at *C* and *D* respectively. The volume of this inclosure is nearly the same as that of the sphere, while its surface is 2.17 times as great.

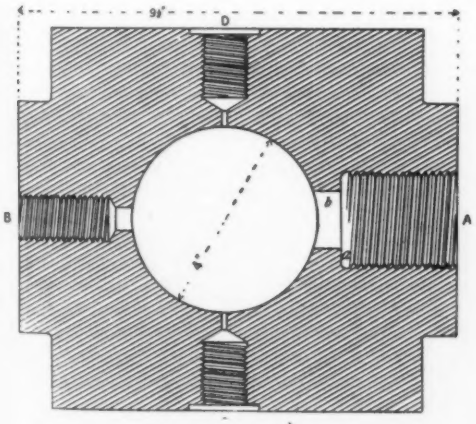


FIG. 5.—SPHERICAL INCLOSURE.

The recording gage screws in at *A*, the firing plug at *B*, and two vaves at *C* and *D* respectively. The spigots, which are turned on the forging at either end (*A* and *B*), fit into a cast-iron stand, to which the inclosure is firmly bolted.

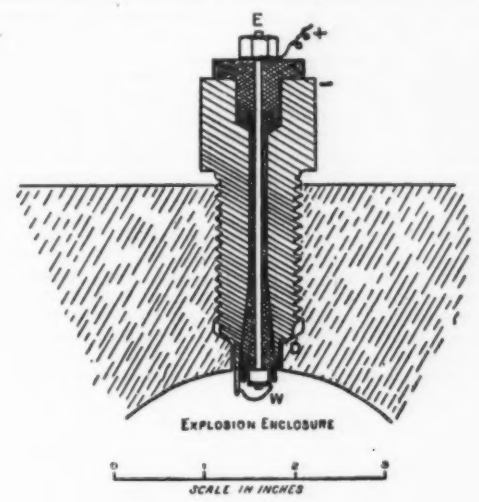


FIG. 7.—FIRING PLUG.

The insulation of the central conductor is cone-shaped, to prevent its being forced out by the pressure of the explosion. A small cartridge of fine gunpowder can, when required, be placed round the fine wire *W*. The gas-tight cone joint, *D*, is protected, in the usual manner, from direct contact with the flame by a projecting piece, which closely fits the aperture in the explosion chamber.

The actual working of this type of recorder has proved very satisfactory. Its time period is sufficiently small to allow records to be obtained not only of the curve of rise of pressure of the fastest cordite, but also of the rapid vibrations which modify the curve under certain conditions.*

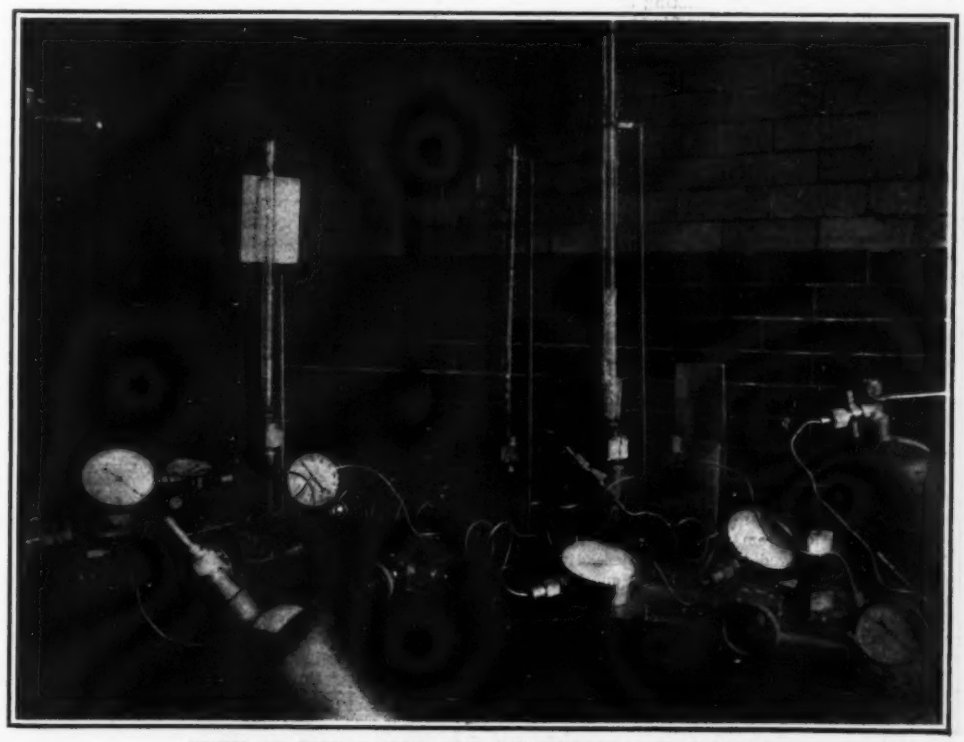
Chronograph.

Owing to the high speed required, the chronograph used for this work had to be specially designed. It is unnecessary to go into all the details of its construction. The ordinary methods were used to measure the velocity of the rotating drum and to insure the constancy of speed during the course of an experiment.

When measuring the rise of pressure during an explosion, a linear speed of between 100 and 1,000 centimeters per second was used. For measuring the fall of pressure during the cooling of the products of combustion the driving mechanism could be geared down to give a linear speed of 5 or 10 centimeters per second.

The drum of the chronograph can be easily detached and taken to the dark room, where the photographic film is wound on; it is then placed in a light-tight box. As explained in connection with Fig. 4, this box is so arranged that the drum can be fixed on to the axle of the chronograph in bright daylight without fogging the film. The box surrounding the revolving drum is pierced with a long and very narrow slit; this, in turn, is covered by a shutter, which is lifted immediately before the explosive is fired and

* Capt. Bruce Kingsmill has proposed the application of this gage to ballistic work with a view to "indicating" a gun in much the same manner as we now indicate a steam engine. This suggestion, which might lead to valuable results, has, as far as I am aware, not yet been carried out in practice.



VIEW OF THE GAGES AND MEASURING APPARATUS.

closed again a second later, after the photograph has been taken.

Thanks to the above arrangement it is not necessary for the room in which the experiments are carried out to be absolutely dark. The mirror of the recorder is illuminated by a straight-filament incandescent lamp, the image of the filament being focused on to the slit of the chronograph camera, forming a straight streak of light perpendicular to the axis of rotation. The beam of light is deflected to an amount proportional at each instant to the pressure in the explosion chamber and, traveling along the slit of the camera in a direction parallel to the axis of rotation, it traces out a curve on the photographic film. The ordinates of this curve represent the instantaneous pressures, the abscissæ the times at which the said pressures existed.

A low-voltage high-candle power lamp is used to illuminate the mirror, the comparatively thick filament of such a lamp giving correspondingly more intense illumination. At the moment of firing, the lamp is switched for a few seconds on to twice its normal voltage, and thus the strongly actinic light required is produced.

The recorder is calibrated by hydrostatic pressure before and after each set of experiments.

Explosion Chambers.

It is well known that the shape of the inclosure has a considerable effect on the behavior of the explosive during combustion. On the other hand, the ratio of the internal surface to the total volume of the chamber determines to a large extent the rate at which the pressure will subsequently fall.

With a view of obtaining some further information on these questions, two explosion chambers were constructed having approximately the same volume, but differing largely in shape. The first, a sphere, offers the least possible cooling surface; whereas the second, a long, narrow cylinder, has a surface more than twice as great.

One of the subjects of the research was to study the oscillations of pressure which are set up under certain conditions. In a long cylinder such oscillations are easily started, but in a small sphere the symmetrical shape and the short distance from wall to wall tend to equalize the pressure existing at each instant throughout the inclosure. Thus, in a spherical inclosure, the pressure rises usually without vibration and forms a smooth curve, the shape of which depends exclusively on the nature of the explosive used. In a long cylinder, however, the normal curve is modified by the distribution of the explosive, the method of firing, and various other factors.

Before designing these chambers, the relative advantages of solid metal and wire winding were fully considered. The latter construction, if properly carried out, adds considerably to the ultimate strength. A system of winding suitable for a spherical inclosure is, however, not easy to devise, and this fact, together with the ever-important consideration of cost, led to the adoption of solid walls.

Mild steel was chosen as the material best suited to withstand the sudden impact of an explosion. The limit of elasticity, ultimate strength, and elongation of test pieces cut perpendicular to the direction of rolling were carefully determined before the forgings were machined.

Spherical Explosion Chamber.

The first explosion chamber is a nearly perfect sphere, 4 inches in diameter (see Fig. 5). The measurements made in a plane passing through the axis of rotation when in the lathe (i. e., in the plane in which any variation from the spherical shape would be a maximum) showed that the greatest divergence from the mean diameter did not exceed one hundredth of an inch.

The cavity was cut out of a solid block of rolled steel through an opening only 1¼ inches diameter, a clever piece of engineering, for which I am indebted to Messrs. Lennox & Co. Exceptional care was also taken to give the inner walls a smooth, polished surface.

The internal volume of the cavity was redetermined by weighing the mercury required to fill it. From these determinations the diameter of the sphere is 10.20 centimeters. The volume is, therefore, 556 cubic centimeters and the internal surface 327 square centimeters.

The minimum thickness of the walls is 2⅛ inches, and the apparatus would doubtless withstand a pressure of 2,000 atmospheres. As, however, the experiments had to be carried out in an ordinary laboratory, under conditions which would have rendered the consequences of an accident disastrous, it was decided not to exceed half this limit. The second inclosure was alone used for higher pressures, it being, as we shall see, of stronger construction.

Apart from the effect of actual pressure, that of the sudden impact or blow given by the more rapid explosives has to be considered. As will be seen below, some mixtures of compressed coal gas and oxygen develop their full pressure in something like one ten-thousandth of a second and, in fact, occasionally detonate. It is difficult to estimate the actual strain produced by a force so suddenly applied.* When we consider that the present work comprised the repeated explosion of such mixtures, it will be seen that exact calculation becomes impossible. In all probability, during the course of the first few explosions of this kind the part of the material nearest the inner surface is strained to beyond its limit of elasticity, and therefore yields. In the case of steel, like the present, having a fair elongation, the first effect is actually to strengthen the inclosure; the inner layers of the steel having been thus permanently elongated are under an initial compression which will help them in resisting further deformation. Aided, however, by the extremely rapid variations of temperature, this effect will in time cause surface cracks. Under successive strains the cracks will deepen to an extent that may become dangerous. Being on the inner surface of the chamber, the extent of the damage cannot be clearly ascertained. In the present work this danger was guarded against by a method which, though perhaps somewhat crude, is at least easily carried out and, *faute de mieux*, may be considered satisfactory. On the outer surface of the inclosure a ring was accurately turned; the plane through the center of this ring passes through the center of the sphere and through the gas and mercury inlets; it therefore encircles the weakest portion of the inclosure. A large micrometer gage was made, by means of which the diameter of this ring was from time to time measured. This micrometer will clearly show an increase of one three-thousandth of an inch on the 8-inch diameter, or a change of about one two-hundredth of one per cent.

Up to the present no variation of diameter has been detected, and it is reasonable to infer that the apparatus has not been strained to a dangerous extent.

A sectional drawing of the inclosure is given in Fig. 5.

The recording gage screws into *A*, the steel ring (*D*, Fig. 3) pressing on to the ledge, *a*, and thus forming a joint. The end of the gage fits closely into the neck, *b*, and protects the joint from contact with the heated gases. The firing plug fits into the aperture *B*.

When gaseous mixtures are to be tested, the two valves which screw into *C* and *D* are brought into use. The cavity is first filled with mercury through *C* and the gas is then forced in through *D*. As soon as the mercury has been driven out, the valve *C* is closed and the pressure and composition of the mixture adjusted by means of the apparatus described below.

After each explosion the sphere is washed out first with a solution of caustic potash, then with distilled water.

Cylindrical Inclosure.

The cylindrical inclosure, shown in Fig. 6, is also made of mild steel.

The dimensions are: External diameter, 12.2 centimeters; internal diameter, 3.17 centimeters; length of bore, 69.64 centimeters. It has, therefore, a capacity of 550 cubic centimeters and an internal surface of 709 square centimeters—roughly speaking, the same volume as the sphere, but rather more than twice its surface. The various apertures are identical to those of the spherical inclosure and the gages and other fittings can, therefore, serve for either apparatus. This cylinder has been used up to 2,000 atmospheres and would doubtless be safe at a considerably higher pressure.

Firing Plug.

The design of the firing plug is clearly shown in Fig. 7.

Standard Gages.

A vast number of measurements of statical pressure had to be made during the course of the work, more especially for the part dealing with gases. For this purpose the connections were arranged so that the gages could be easily interchanged, each one being used for the range over which it was most sensitive. To determine the initial pressure and composition of the gaseous mixtures, two independent sets of observations were always taken. The pressure was first roughly adjusted to the desired amount by means of direct-reading Bourdon gages, then accurately measured by a standard gage. A series of mercury columns were used for the lower pressures and manometers of the Cailletet type for the higher pressures. The various small modifications introduced in the construction of the latter instrument, though they added to its reliability, are not of sufficient importance to warrant a more detailed description.

Three gages of this pattern were in use, the first reading from 3 to 12 atmospheres, the second from 12 to 50, the third from 50 to 200.

Valves and Connections.

The various valves by which the flow of gas is regulated are of the type shown in Fig. 8.

The gas inlet is at *A*, whereas *B* is connected to a gage which indicates the pressures behind the valve. A fine screw-thread is cut on the spindle, *S*. By turning the wheel, *W*, the conical end, *F*, of the spindle is lifted slightly from its seat and the gas flows to the part of the apparatus connected to *C*. To avoid any sudden rush of gas the spindle bears a slightly tapered prolongation, which nearly fits the outlet, and, therefore, several turns of the screw are necessary to give the full opening.

The many connections required throughout the apparatus are all cone joints of the type shown at *C*.

The female connection ends in a hollow cone, the angle being about 100 degrees. The male, *D*, a cylinder of brass, an inch or two long, ends in a hemisphere, which is pressed into the cone by the nut, *N*, the inner surface of which bears upon a ring, *R*. Into this cylinder the copper tube is soldered for a distance of about three-quarters of an inch. These cone joints are superior to the lead washer joints, inasmuch as they are easily made or disconnected, last indefinitely, and remain gas-tight under all pressures.

(To be continued.)

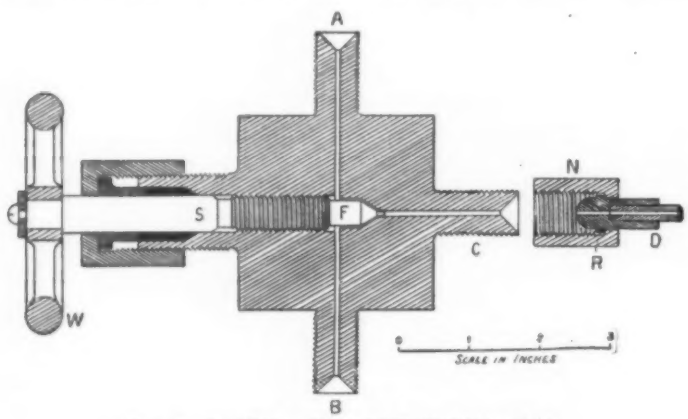


FIG. 8.—VALVE AND CONNECTING CONE.

The numerous valves that were required during the research were all substantially of the type shown in this figure, though varying considerably in external shape according to the use for which they were intended. The above design was used for the valves serving to regulate the initial pressure and composition of the mixture in the experiments on gaseous explosives. The apparatus is fixed firmly to the working bench by screws (not shown in figure) passing through the four corners of the metal block.

* It is usual to take an instantaneous load as equivalent to twice the same statical load. In the present case, however, we have to deal with the momentum of the gas itself, which is traveling at an enormous speed.

THE BURNING COAL BEDS OF UTAH.

THROUGH a long line of cliffs from Colorado to central Utah and then southwest toward Arizona, extensive beds of coal are found, and recent geological investigations into this coal formation of the far West have developed what may be termed burning mountains, or coal beds, afire, with surface indications of constant combustion for ages past.

Like other coal-producing States of the Rocky Mountain region, the coal fields of Utah are somewhat widely separated, and even the known fields have been comparatively little explored; therefore very little is known of their productive area.

The edges of these beds come to the surface in these cliffs nearly one thousand feet above the bordering desert, and in ages past this coal has burned into the mountain cliffs until smothered by the accumulations of ashes and covering of superincumbent rocks. In places, the heat of this burning coal has been so intense as to melt the rocks. From surface appearances, the fires have gone out in these cliffs, but at one point in the canyon of Prince River where the coal is being mined, the rocks are found to be uncomfortably hot, and the miners were compelled to retire for fear the fires would break out.

Other coal fields lie in the desert west of Green River. At two places near tributaries of Fremont River the coals are burning, and have been without cessation since they were discovered by the earliest explorer. At certain intervals, as the burning of the thick beds progresses, producing cavernous spaces in the earth, the rocks cave in, forming vents for the freer circulation of air. Then the coal burns more fiercely, and the heat becomes so intense as to even melt the rocks.

The origin of these fires has been the subject of much speculation. Three explanations are commonly heard among the people—the Mormons who inhabit this peculiar country where the mountains burn:

(1) One explanation is that lightning has by chance struck the edges of these coal beds at various times since these mountains were lifted up.

(2) Another is that forest fires raging in the mountains came in contact with exposed coal. The more thoughtful point out that the forests in this desert region are too sparse for forest fires to occur.

(3) Still another, and more common explanation, is that the Indians built their camp fires under the protecting ledges of the mountains against the coal, and it was thus ignited. They point to the fact that there are ruins of the habitations of cliff dwellers here, and that in their day the coals began to burn.

The coal miner in this region sees still another possi-

ble cause for these fires. In the dry mines—and most of them are dry mines—they observe that when a quantity of water is thrown upon a heap of dry coal, it spontaneously begins to burn, and if not protected will burn the mine.

Now it can be seen that if the rocks are rent by some subterranean cause, as sometimes happens, there may be a sudden access of water to the fresh, dry coal, causing spontaneous combustion.

ENGINEERING NOTES.

Under all ordinary conditions, condensation is so great as to warrant a considerable expenditure for its prevention, and the most practical method of lagging cylinders and other surfaces transmitting steam in a locomotive is to make a design such as will locate these parts where they will be less exposed and then make use of a good non-conducting lagging, having the minimum facility for conveying heat, properly applied, which will result in as practical means to prevent radiation as can be arrived at at the present time. A variety of methods to prevent radiation, such as steam jacketing, dead air spaces, and other processes favorable to sluggish conduction, have been attempted from time to time but without satisfactory results.

The new recuperative boiler which has been devised by M. Maurice, engineer-in-chief of the French Marine, is attracting considerable attention, seeing that it is operated upon a novel and original plan. This invention was awarded a prize at the end of the last year by the Académie des Sciences. The new recuperative boiler has the property of being able to keep on supplying steam for several hours after the fire has been extinguished. The principle of the storage of heat consists in the use of a mixture of salts having a great specific heat and surrounding the greater part of the tubular system of the boiler. The temperature of these salts rises to about 450 degrees C. during the heat. The result forms a new solution of the problem which was formerly solved by the use of reservoirs of superheated water, and here we have an economy of weight as well as space. After the heat which has accumulated is exhausted during the run after the fire is extinguished, the accumulation of heat is again made very quickly after the fire is started. The system is of special value in the marine, and also in electric stations. The result of the first experiments which have been made at Cherbourg are quite favorable, and no doubt the system will be applied afterward on a larger scale.

In spite of the reiteration by medical men of their belief in the importance of hygiene and preventive medicine as a part of the equipment of the medical profession, it is a significant fact that in America even the best medical schools devote very little time to any adequate instruction in these subjects. It may be that this is wise and that the pressing necessities of practical medicine forbid any extended instruction in public health science. The community must look for the most part elsewhere than to medical men for adequate investigation, legislation and administration of public health science. Medical men must, of course, always participate in the work, in connection, particularly, with the control of epidemics and in those forms of preventive medicine which have to do with vaccines, serums and other means of modifying the vital resistance of the human body. But as regards the care and control of the environment, medical knowledge is not indispensable, and the entrance of the engineer and the sanitary expert upon the field, as foretold by Dr. Bowditch nearly twenty years ago, is to-day a conspicuous, and probably a wholesome, fact. As to the attitude of engineering education toward public health science there can be no question. Engineers are bound in the future to take constantly a larger and more important part in public health work, and must be informed, and if possible trained, accordingly. Moreover, as regards both medicine and engineering, the problem is by no means insoluble, for a very short course of instruction rightly given would easily inculcate the necessary fundamental principles, while electives or post-graduate work might enable those few whose tastes led them in this direction to investigate and specialize and more thoroughly prepare themselves for public service.

"One machine—one tool—one man," was the old rule since the operation of the first machine, and if some short-sighted trades unions had their way, would still be in force. But such is no longer the case in live machine shops. Many single-spindled drills are, for special work, replaced by multiple-spindled drills, so that with one operation half a dozen or more holes are drilled, gaining very greatly in time and also in having the output absolutely interchangeable, a point of the very highest value. Single-headed planers are now the exception, except in small sizes; planers cutting on both the forward and return stroke have been used, but are not generally approved; plate edge planing machines cut both ways with entire satisfaction. Lathes also have multiple cutting tools, two, three and four. Locomotive driving-wheel lathes, for example, can have the two wheels and two bearings machined simultaneously, though duplex machines are the general ones used. Shafting lathes have usually three tools operating, gun lathes four, etc. Vertical boring mills have usually two heads. Turret lathes in their many modifications are a slightly different example of multiplying tools. The different tools are contained in one machine, but usually one tool operates at a time, the saving in time being effected by the extreme ease of changing from one tool to another. **Screw-cutting machines with multiple spindles** are now universal, so that the price per operation is reduced to a minimum. What a difference between the time when every screw was cut in the lathe, or by hand dies, and present-day practice, when, for example, the operator has to thread 15,000 half-inch bolts in a day to make a living wage, as is the case in a Pittsburg shop! The milling machine is another example of duplicating tools, though in a slightly different sense. The milling cutter may have twenty to thirty cutting edges, each doing its fair share of work, and each is as distinctly an individual tool as the cutters in a boring bar, for example. Besides this, a milling machine may have several heads. Milling machines have been productive of immense economy in the machine shop, not only in the decrease in time for the operation, but also in facilities offered for milling any kind of profile.

ELECTRICAL NOTES.

One argument often brought up against the old belt-driven machine shop was the great waste of power, and the same is brought up against the use of individual motors as against group driving, on account of the lower efficiency of small motors, but the argument is not worth considering when the total amount of the power consumed is taken account of. The cost of power is very rarely 2 per cent of the cost of the output in shops of any size. Suppose by the strictest economy 50 per cent of the cost of power could be saved, yet the net saving would be only 1 per cent. During the year 1904 the total cost for power at the Pittsburg & Lake Erie shops was slightly over one-half of 1 per cent of the cost of the labor and material.

It is accepted by the engineering world that the success of a railroad depends, first, upon its location, and second upon the engineering skill used in its installation. These same conditions will govern the success of electric traction as applied to steam roads, the first requirement being the selection of a suitable portion of the road to change over, and second, the engineering skill exercised in the selection of a suitable system, which involves the choice of voltages, types of motors, use of motor cars or locomotives, etc. The conditions affecting the desirability and possibility of making a change are: Effect of gross receipts; effect on operating expenses; effect on interest charges. Where it can be shown that the increase in gross receipts with a relative decrease in operating charges will result in a fair margin above the increased interest charges for electric power, development may be expected entirely independent of the general advantages to the traveling public.

Consul Keene, of Geneva, tells of experiments with a wonderful new electric searchlight for war purposes. He writes: "At Caux, on the Lake of Geneva, at an altitude of 3,600 feet, E. Cuenod submitted to the officers of the Swiss general staff a new searchlight. It is reported as having been a success, as the searchlight was handled with the greatest ease, sending its powerful rays a distance of over 7½ miles. Objects at 6½ miles could be distinctly seen. The machine providing the power was a 24-horse-power and furnished a 1,000,000 electric candlepower light. A 40-horse-power motor would give 12,000,000 electric candlepower. Diameter of projector was 3.28 feet. The great advantage of this searchlight is that it may be electrically handled in all directions by wire from a distance of 656 feet from the motor car, which transports it and sends it to the required spot. It thus enables the driver and observer to send the rays to any place they desire without being blinded by the light, and places them under shelter from the enemy's fire. The new searchlight has already been submitted to certain high French officers, and will shortly be examined by the German general staff."

The idea of the electron has grown out of the idea of ions as used in electrolysis. Each molecule of an electrolyte may break up into two ions, i. e., two atoms, or groups of atoms, carrying equal and opposite charges. The current passing through the electrolyte then consists in the actual transfer of these ions to the cathode and anode to which they give up their charges. In his Faraday lecture, delivered in 1881, which marks an epoch in the ion theory, Helmholtz says: "If we accept the hypothesis that the elementary substances are composed of atoms, we can not avoid concluding that electricity also, positive as well as negative, is divided into definite elementary portions, which behave like atoms of electricity." These "atoms of electricity," since encountered in a large number of more recondite phenomena, and often apparently free, i. e., not attached to any matter in the ordinary sense, are the electrons. Thus physicists have been led to return in a certain sense to atomistic conceptions, without, however, abandoning the idea of the propagation of electric, magnetic, and optical disturbances through the ether in time. Lord Kelvin, in his Baltimore lectures in 1884, gave expression to this tendency so largely developed in the succeeding twenty years. The very first words of his first lecture are: "The most important branch of physics which at present makes demands upon molecular dynamics seems to me to be the wave theory of light." The phenomena exhibited by cathode and canal rays, Röntgen rays, the Becquerel rays emitted by radium, etc., all find their ready interpretation in this theory. At the same time, the electron theory as developed by Lorentz, Wiechert, Drude, and others seems to furnish an excellent basis for the whole theory of electricity, magnetism, and light. Indeed, attempts have already been made of interpreting matter itself as an electro-magnetic phenomenon and of explaining gravitation by means of this electron theory of matter.

TRADE NOTES AND FORMULÆ.

Substitute for Cork and Cork Wood.—This substance is provided, in general, by the treatment of wood pulp or other ligneous material with certain other substances. For the success of the composition it is necessary that the constituents be mingled and treated under special conditions. These materials are wood pulp, the pith of corn stalks, gelatine, glycerine, and formic aldehyde. The volumetric proportions in which these constituents combine with the best results are the following: Wood pulp, 3 parts; cornstalk pith, 1 part; gelatine, 1 part; glycerine, 1 part; water, 4 parts; 20 per cent formic aldehyde solution, 1 part; but the proportions may be varied. The substance is formed in the following manner: After disintegrating the ligneous substances, and while these are in a moist and hot condition they are mingled with the solution of gelatine, glycerine, and water. The mass is stirred thoroughly so as to obtain a mixture as homogeneous as possible; the excess of moisture is removed by any known method. As a last operation, the formic aldehyde is introduced, and the mass is left to coagulate in this solution. The formic aldehyde renders the product insoluble in nearly all liquids. So, it is in this last operation that it is necessary to be careful in producing the composition properly. When the operation is terminated, the substance is submited to pressure during its coagulation, either by molding it at once into a desired form, or into a mass which is afterward converted into the finished product.—Rev. des Produits Chimiques.

Industrial Employment of Alcohol.—The industrial employment of alcohol was the subject of various communications at the recent convention of the alcohol manufacturers of Germany. Herr Wittelshoefer furnished the following description of apparatus making use of alcohol, sold during a period of four months: Apparatus for heating, 62,480 pounds; apparatus for reheating with alcohol, 19,360; lamps, 37,400. This was an increase over the same period of the previous year, when the figures were respectively 48,180, 6,600, and 15,840.

Herr Meyer presented a comparison between alcohol, petroleum, and gasoline, as a combustible in explosion motors: 2.2 pounds of alcohol of 90 deg., costing 5 cents, develop 5,500 calories; 2.2 pounds of gasoline, costing 6 cents, develop 10,300 calories; 2.2 pounds of petroleum, costing 5½ cents, develop 10,300 calories. One thousand calories, therefore, cost 0.9 of a cent with alcohol; 0.57 cent with gasoline; and 0.53 cent with petroleum. Still, he regards this difference in price as counterbalanced by the superiority of alcohol with reference to its yield in the employment for motors. The yield of the best steam boilers does not exceed 15 per cent of the total heat developed. In the improved alcohol motors the yield reaches 33 per cent; in gasoline 21 per cent; and in petroleum motors 18 to 19 per cent.

For illumination Wittelshoefer has estimated that the Auer alcohol lamps consume 4.4 ounces of alcohol, costing ¾ of a cent, for 50 Hefner candles; a petroleum lamp causes a consumption of 3.5 ounces, costing ½ of a cent, for a light of 24 Hefner candles. These prices were based on a previous condition of the market. At present, lamps are constructed giving 20 Hefner candles for a consumption of 3 cubic inches of alcohol, or 10 Hefner candles with a consumption of 0.8 to 0.9 cubic meters.—Chemik.

Production of Oxygen by the Compagnie Française de l'Acetylene Oissous.—It is known that a mixture of combustible substances and chlorates, when the proportions nearly approach those corresponding to the complete combustion of the combustible matter by the oxygen available in the chlorate, ignites with great facility; so great, even, that the reaction generally is of an explosive character. A mixture thus formed is not a source of oxygen, but simply a source of heat. If a mixture is prepared in which a slight proportion of combustible substances is brought into the presence of a great excess of chlorate, the total mass of the chlorate may be considered as formed of two parts, one of which exactly corresponds to the complete oxidation of the combustible substances, but ready to be decomposed with disengagement of oxygen under the action of the heat produced in the course of the combustion.

To obtain oxygen as a product under determined pressure, it is sufficient to operate in a close receiver, the volume of which with reference to the mass of oxygen liberated is in inverse ratio to the pressure. Any combustible matter may be employed—divided metals, charcoal, hydrocarbides, cellulose and similar products. If the products of combustion contain gaseous impurities capable of interfering with the employment of the oxygen thus prepared, there must be eliminated by suitable absorbents, such as lime or potash, in order to remove the carbonic acid. The decomposition of the chlorates gives rise of itself to a certain disengagement of heat. It may, therefore, be feared that the operation will assume an explosive character under high pressure. This is obviated by previously adding to the mixture an inert matter, such as sand, clay, or infusory earth, which, as in the case of nitro-glycerine, renders the mass much less sensitive to explosive influences. For the same purpose fusible substances may be employed; the superabundant heat disengaged in the course of the reaction will disappear in the form of latent heat in the fusion

of these substances. It may be convenient in many applications to present the mixture in calculated portions, so as to free a given quantity of oxygen. This can be done by inclosing the mass in cartouches, or by molding it into blocks of convenient dimensions.—Chemik.

SCIENCE NOTES.

The migration of compounds, particularly of those containing nitrogen, magnesium, and potash, to growing vegetative parts and to the developing seed is most remarkable. The production, whether regulatory or otherwise, of the numerous by-products in the cell, such as tannin, pigments, organic acids, etc., is also of peculiar interest. The functions of some of these compounds must be most important, and should receive further attention. Tannin, particularly, is doubtless of much economic importance in the regulation of turgor and in augmenting the resistance to injurious external agents. Astruc has recently shown that acids are found in the younger parts of non-succulents and mostly in the region of maximum turgescence; and that there is a progressive decrease of such compounds in the older organs. In succulents, moreover, very slight changes in the external conditions materially affect the acid content.

A reversal of chemical change can take place under the influence of temperature, of electricity, of light, of pressure. And the easiest way to arrive at a measure of chemical affinity is presented in the last case, as was foreseen by Mitscherlich. Let us take gypsum as an example. Burnt commercial gypsum, mixed with water, will combine with the water. We know that this chemical change can produce pressure, and that it may be prevented by sufficient pressure and be reversed by it, as Spring succeded in pressing out sulphuric acid from sodium bisulphate. And it is possible in such cases exactly to determine the limiting pressure, such that a higher one presses out the sulphric acid while a lower one is overpowered by the affinity action. If the chemical change takes place under a pressure only slightly less than that which would prevent it, thus practically taking place under the limiting pressure, we get out of affinity the greatest quantity of work that it can possibly produce; and this quantity is the same whatever the nature of the opposing action, be it electricity, light, or anything else. Therefore, in this maximum work we have a sound measure of affinity.

The results of geographical research show us that in many parts of the world climate must have greatly changed in comparatively recent times. In the now arid regions of northern Africa, central North America, and in parts of Asia, there is ample evidence that the climate was in times past more humid. In a remarkable paper on the causes of changes of climate, contributed by Mr. F. W. Harmer to the Geological Society in 1901, and which has not obtained the notice it deserves, it is pointed out how changes in the distribution of the prevalent winds would vastly alter climatic conditions. Like everything else in nature, and especially in the department of meteorology, these questions are exceedingly complex, and similar results may be brought about in different ways; but there can be no doubt that the climate of South Africa would be greatly modified, and more rainfall would occur, if only the cyclonic storms which now chase each other to the eastward in the ocean south of the Cape of Good Hope could be prevailed upon to pursue a slightly more northerly line, and many obstacles to the agricultural prospects of South Africa now existing would be removed. This is, however, beyond the powers of man to effect; but there are other ways of attaining the object, and it is earnestly to be hoped that the attention now being paid to afforestation may result in vigorous efforts to bring about by this means the improvement in humidity so much required in many parts of the country.

The recent researches which A. Dubois carried out at Paris enabled him to discover several new compounds, these being the iodo-mercurates of calcium. Since the work of Boullay, which dates from 1827, the constitution of these bodies does not seem to have been definitely fixed. Using heavy liquids having iodide of mercury as a base the author was led to find three double iodides of mercury and calcium. The process is as follows: We dissolve iodide of calcium and biiodide of mercury in lukewarm water, to saturation, ending with a slight excess of the former. The filtered solution has a density of 2.89. When slightly cooled, it deposits large yellow crystals which are very deliquescent. These crystals have the formula CaI_2, HgI_2, H_2O. They are soluble in water and the alcohols, but are insoluble in chloroform or benzine. To form the second body we use the mother liquid of the above, adding iodide of mercury and heating the solution. When cooled near the freezing point it deposits very small crystals which are well defined and less deliquescent than tue former. If we lower the temperature of the liquid below the freezing point the former crystals increase in number and a new set is deposited, having the form of long prisms attached together and streaked lengthwise. These crystals measure from 0.4 to 0.8 inch in length. The second iodo-mercurate has the formula CaI_2, 5 HgI_2, 8 H_2O. A corresponding product can be obtained with strontium, having a density of 4.7. Water decomposes it and gives a red precipitate of mercuric iodide. The formula for the third compound is 3 CaI_2, 4 HgI_2, 24 H_2O, and its density is 3.60. It is quite soluble in alcohol, glycerine, etc., but insoluble in chloroform. Water has the same action as above.

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TABLE OF CONTENTS.

PAGE

I. ASTRONOMY.—Star-streaming 25371

II. AUTOMOBILES.—Cost of Running a Motor Delivery Tricycle... 25371

III. BOTANY.—Harvard's Botanic Garden.—By MARY CAROLINE CRAWFORD.—5 illustrations 25366
Hybridization of Plants 25370
The Direction in which Plants Twine.—1 illustration 25370

IV. ELECTRICITY.—Electrical Notes 25375
Recent Advances in Wireless Telegraphy.—By J. ERSKINE MURRAY 25365

V. ENGINEERING.—Engineering Notes 25375

VI. HYDRODYNAMICS.—Water Power at High Pressure 25368

VII. MECHANICAL ENGINEERING.—The Development of the Torpedo-boat Destroyer.—By W. J. HARDING.—5 illustrations.. 25369

VIII. MINING AND METALLURGY.—The Burning Coal Beds of Utah 25374

IX. MISCELLANEOUS.—Cement Mortar and Concrete: Their Preparation and Use for Farm Purposes.—III.—By PHILIP L. WORMLEY, JR.—4 illustrations 25364
Science Notes 25376
Trade Notes and Formulæ 25375

X. MUNICIPAL ENGINEERING.—Pavement for Residence Streets 25363

XI. PHOTOGRAPHY.—A Simple Camera Shutter.—1 illustration... 25365

XII. PHYSICS.—The Pressure of Explosives. Experiments on Solid and Gaseous Explosives.—I.—By J. E. PETAVEL.—10 illustrations 25372

XIII. TECHNOLOGY.—Bleaching of Flour 25363

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